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The Institute of Vitreous Enamellers

The Welsh Engineers' and Founders' Association

and

The Foundry Trades' Equipment and Supplies Association

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The Present Position of Foundry Mechanisation

There is something of the order of eighty mechanised foundries in Great Britain, and this method of making castings is now so well established that it seems opportune to consider just what fields have so far been covered, and to what extent. The motor-vehicle foundries rank amongst the most completely mechanised foundries. The incoming raw materials are machine-handled, and the core-making department is interlocked with the mould assembly. Radiator manufacture as an industry is almost entirely mechanised. Most of the electrical engineering establishments have conveyorised the production of their lighter castings. Much of the gas cooker business has gone over to this system, whilst the railway companies have started manufacturing some lines of castings on the continuous system, but so far have not included the chair foundries. Amongst heavier castings, ingot mould manufacture has been partially mechanised, but for the industry as a whole much still remains to be done. Generally speaking, fettling methods could be improved upon. Another phase of heavy castings manufacture which is in course of being put into operation involves the continuous supply of sand by means of tapping from an overhead source to mobile Sandslingers, which work along the bay of a foundry. Beneath the foundry floor is a return sand belt surmounted by a grating so that the circuit can be completed anywhere along the shop, giving a well-ordered manufacturing cycle. It is a thought that such a system needs transfer cranes to handle the castings, boxes and patterns in and out of the bay at right angles, otherwise congestion of the overhead cranes might be experienced. We confidently expect that this system will eventually find its way into the marine engineering foundries.

To return to the lighter type of castings, the following additional castings are made under quantity - production conditions :—Manhole covers, domestic wringing machines, baths, builders' castings, especially air bricks. This last-named casting we have seen being made in home-made yet highly mechanised plant, where the total number of men employed, including the owners, will not exceed a dozen. The question of the manufacture of builders' castings still seems to be debatable. They are being made successfully, but a halt has been called in the last year or so, although we are of opinion that finality has not yet been reached. Rainwater goods manufacturing is a business hedged in with all sorts of commercial conditions, traditions, restrictions, and artisan skill, all of which have their repercussions on modern production methods.

There are many fine examples in Great Britain of core shop mechanisation; the East and West Midlands and West of England can all provide outstanding cases of efficient manufacturing methods. Some of the textile machine manufacturers of Lancashire and Yorkshire have well laid-out shops. Fettling departments, too, have received a modicum of the attention they warrant in recent years, but there is still need for a general smartening up, and in many cases a thorough re-equipment. Too many crazy benches, old-fashioned grinding wheels, irregularly laid floors, and inadequate handling appliances are still evident. A few lengths of roller pathways would make a profound difference.

The malleable foundry industry has to rely on the cupola if it wishes to adopt continuous casting, and one plant of outstanding efficiency is working on these lines. Others have paid special attention to their core shops, but it seems to be in the direction of melting plant that most of the malleable ironfounders have directed their energies in recent years. As a more orderly method of production, the continuous annealing furnace appeals to us, as it eliminates most of the space required to take care of the whole of the output of a stove and the ingoing charge at the same time. With a continuous plant such as we have examined, as one box of castings leaves the furnace, another one is charged in. Thus at any given time for one furnace there is one box to be filled and one to be emptied. Obviously it is not an easy task for the furnace designer to synchronise speed through the furnace with the essential temperature cycle, but it can be done. This system well fits in with mechanised methods of manufacture.

It is not so easy, fundamentally, to mechanise a steel foundry, though with high-speed baby-Bessemer converter practice a continuous supply of liquid metal is available. Not all steel moulds are cast up green, and if they have to be dried added difficulties present themselves. Then the finishing of steel moulds often involves the insertion of several hundreds of spriggs, which again causes pauses in manufacture. The main factor, however, is the rarity of long runs of similar castings. Colliery tub-wheels— a possible exception—have already been the subject of a serious attempt at mechanisation. Owing to the thicknesses of the coal seams worked, there are a number of varieties to be

(*Concluded on page* 152.)

Correspondence

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

Tropenas Practice

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—In your issue dated July 14 you published a record of an achievement by Archibald Baird & Son, Limited, of Hamilton, the record being twenty-two 2-ton Tropenas heats in 5¾ hrs. out of one converter. No details are given as to the state of the metal at the commencement of the blow. It would be interesting to learn whether the metal had been partially refined before being run into the converter, for, if not, a very big percentage of steel scrap must have been used to give a very soft material before blowing. In such a case, one would expect very high sulphur contents in the steel.

Surely such steel-making practice should be kept quiet and not publicised. Taking the average all-in time for a heat as something in the region of ¼ hr., it does not permit the production of good, clean steel. Steel made at this speed could never have been thoroughly killed, and it would be interesting to know if this steel would satisfy Admiralty requirements.—Yours, etc.,

H. TAYLOR, B.Sc.

36, Thorntree Drive,
West Monkseaton, Northumberland.
August 19, 1938.

[A copy of the above letter was sent to Archibald Baird & Son, Limited, whose reply is appended.—EDITOR.]

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—The following information will, I think, answer all Mr. Taylor's points.

The metal at the commencement of each blow was a mixture of hematite pig-iron and selected steel scrap, giving a silicon content of 1.5 to 1.7 per cent., tapped hot from a cupola. This metal was desulphurised before going into the converter, and the sulphur in the finished steel in every case was under 0.03 per cent.

The steel was clean and thoroughly killed. It remained 8 to 10 minutes in the ladle before casting. Actually, 85 per cent. went into Admiralty castings, and all test-pieces were well over Admiralty "A" quality requirements.

We think it is to the benefit of the trade that progress which has taken place in recent years in the Tropenas converter furnace should be brought before those who are interested and who are able to appreciate good steel-foundry practice.—Yours, etc.,

HARRY A. BAIRD.

Archibald Baird & Son, Limited,
Hamilton.
August 23, 1938.

Budgetary Control

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—With reference to my article on "Budgetary Control and Standard Costs," I notice that in the issue of the JOURNAL dated August 25, the following appeared:—

	£ s. d.	£ s. d.
Metal cost of rough casting 84 lbs. at £5 per ton	3 15 0	(0 3 9)
Less runners and risers, etc., 28 lbs. (84—56) at £4 per ton	1 0 0	(0 1 0)
Metal cost of finished casting	2 15 0	(0 2 9)

It appears that in this calculation ¾ of a ton and ¼ of a ton have been taken instead of ¾ of a cwt. and ¼ of a cwt. The figures in brackets are the correct ones, and I apologise for this error.—Yours, etc.,

T. MCALPINE.

156, Meads Lane,
Seven Kings, Essex.
August 26, 1938.

Valve Design

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—The article in your issue of August 25 entitled "A Fault in Gate Valve Design and its Correction" would appear to suggest that the author claims a new feature. Lest this should cause some misunderstanding, it should be pointed out that leading valve makers have manufactured and catalogued the fitments shown in Figs. 2 and 3 for many years.

It is then only necessary for purchasers to specify their need for either of these cleaning holes to ensure that they will be included in a quotation or order.

There is, of course, some slight additional cost over that of the valve without such a fitment, and it is probable that in some cases the considerations of false economy have been the means of valves being installed without them, even though conditions have called for their use.—Yours, etc.,

JAS. LIVESEY.

3, Howard Park Drive,
Kilmarnock.
August 29, 1938.

Institute of British Foundrymen *versus* British Works Managers' Association: Third Annual Cricket Match

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—As already indicated by you, the above match will be played next Sunday, September 4, on the Cricket Ground, Whittington Barracks, Lichfield (by kind permission of the O.C. Troops, Lichfield). The match will commence at 2.30 p.m. A number of friends will assemble for lunch at the George Hotel, Lichfield, at 1 p.m., and tea will be served on the ground.

I have received sufficient promises from players to enable me to form a team. I shall be glad if all those members, their ladies and guests who intend to be present will let me know not later than Saturday morning, September 3, in order that I can complete the catering arrangements.—Yours, etc.,

J. E. HURST.

Darlaston Blast Furnaces,
Darlaston, Staffs.
August 29, 1938.

The Present Position of Foundry Mechanisation

(*Concluded from page* 151.)

made. Superficially such a casting looks as though it could be made of chilled cast iron, much in the same way as the Americans make their chilled car wheels, but in pits it is customary to make the tubs or trams into temporary buffers by inserting a sprag between the spokes of the wheels. To us it seems a little primitive, but we are trespassing into a field about which we have to rely on secondhand information. Another difficulty in the mechanisation of a steel foundry, not, of course, insurmountable, is the general demand for facing sand in addition to backing sand. The iron moulder working in or near a mechanised plant is now usually quite content to use a general-purpose sand, but this enthusiasm has yet to spread to the steel moulder.

Relatively very little has been done in the direction of mechanising non-ferrous foundries, though there are some outstanding exceptions. Cases exist where the Sandslinger is used, and where the core shops are completely conveyorised, but, generally speaking, the batch method of casting still persists. With the extended use of quicker melting furnaces, it is becoming customary to cast up much more frequently, and one pair of moulding boxes may be used several times in one day.

Random Shots

Football has made its appearance once again, and Saturday afternoons will be well booked-up for the next six months or so. There are, "Marksman" supposes, some foundrymen who do not make a habit of watching their favourite team each week, but for them there will be plenty of Branch meetings to attend, and for the unfortunate few more than enough of committee meetings! The poor Aberdonian who walked all the way from Scotland last season in order to see the Cup Final and then was too tired to climb over the Stadium wall would be well advised this year to start his trek when the "Minnows" set the Challenge Cup ball rolling next Saturday. He should be able to take it in easy stages.

* * *

Apropos of football, Mr. Percy Fox-Allin tells a good yarn of the days when he used to play Rugger. Having set out one Saturday for a game, he learnt at the last moment that the fixture had been cancelled. On his way back to the station he met a team to which he attached himself, as they were short of a man. The captain asked what position he played, and he said he could play anywhere on the field except full back. On reaching the dressing room he remarked that they seemed to be more than one man short, but the captain assured him that he made up the eleven. It was only at that moment that Mr. Fox-Allin realised that he had hitched himself to an Association team! But he kept the discovery to himself and enjoyed a rollicking good game. The following week the team was fined for fielding an unregistered man!

* * *

At the annual cricket match between the foundrymen and works managers it is to be hoped that the foundrymen's team, with its Yorkshire captain, will keep up that county's proud record. It is definitely sure of the championship. It provided five men towards the last England eleven, with its gigantic score against the Australians, besides claiming the national hero, Hutton, as one of its sons.

* * *

Yorkshire also keeps in the swim, for the latest Channel swimmer comes from Rotherham, and he only learnt to swim about five years ago. Rotherham seems to be a breeding place for swimmers, for did not Burgess come from there too?

* * *

Two fettlers from Rotherham were out of work and decided to go "on tramp." They got about as far as Scoles Coppice when they came across the village blacksmith, whom they asked for work. "Aye, I can give ye a job," he said. "Shoe this horse for me while I go for a bite of dinner." On his return the fettlers asked the blacksmith what he thought of their work. "You've made a tidy job of it, me lads, but why on earth is the horse standing so queerly?" "Well, it was like this, you see, Mister," was the reply, "we had such an awful job to get his hoof into the vice!"

* * *

The latest schoolboy howler comes from Scotland, where a pupil declared that "A foundry is a place where lost articles are taken to and restored to their owners."

* * *

For the benefit of those going to Poland, "Marksman" has been looking up a few Polish words that might come in handy. These include Mansion, Cobra, Kiwi and Ronuk. It is interesting, too, to note that the ladies agree with their husbands—but only in person and number. Just to show their contrariness, they invariably add the feminine "a" ending to their surname. Not that that makes any difference from the English point of view, for any Polish name sounds like a sneeze, with perhaps an occasional hiccough in the middle.

"MARKSMAN."

Cast Iron in the Last Hundred Years*

By Professor E. DIEPSCHLAG (Breslau)

The years between 1830 and 1840 had a decisive influence on the development of cast iron. They saw the establishment of an art which was to serve as a basis for the general progress subsequently recorded in the field of cast iron. They represent the period in the course of which steam engineering, during its rapid growth, gave a tremendous impulse to foundry practice.

Cast iron had been known for centuries. As long ago as towards the end of the 14th century, the art of making iron castings was practised. In the first half of the 15th century the production of cast iron in the blast furnace is mentioned. Since its discovery in 1794, the cupola furnace developed rapidly as the most suitable piece of apparatus for remelting pig-iron. The art of moulding had its prototype in the very ancient art of bronze founding and was subsequently developed until the closed sand mould was produced in the 16th century.

It is certain that the applications of cast iron were limited to a few particular fields of use. First of all, cast iron was employed for casting ornamental plaques, the manufacture of stoves and fireplaces and for making tombstones. It was also used for making cannon balls and sometimes for the barrels of cannon. Since the 16th century, it had been used for making pots, and during the 18th century for kitchen utensils and pipes. The first steam-engine cylinders were in fact merely large pipes and could be moulded and cast without difficulty.

Watt's Invention

The discovery of the steam engine by James Watt is the origin of the epoch of the great technical progress which iron founding was to experience. At the commencement of the 19th century, the steam engine was slowly preparing to transform the whole of the former manual work into mechanical work. The steam engine builder was obliged to make modifications in the original form of the engine in order better to adapt it to the requirements of each particular case. The existing machine tools had to be adapted to the ever-increasing power of production of the steam engine and new methods of working had to be perfected. An incredible number of new projects and plans were disclosed, some of which led to interesting results, while others proved fruitless.

When the science of the steam engine had no longer any considerable modifications to undergo, progress was at first directed towards improving and perfecting the engine which had been evolved. The construction of the steam engine was followed by that of hydraulic engines, pumps and blowing engine cylinders.

Railway Progress

The principal sphere in which the most marked progress was recorded, however, was that of the railways. In 1830, railways were being constructed in all the principal countries and this construction absorbed considerable quantities of cast iron. At that period, the steam engine was already being employed in shipbuilding.

The following figures may be cited for example to show the rapidity in the growth of the use of the steam engine: In 1784, there were two steam engines in France, while in 1834 there were already 1,105. During the latter year, there were constructed in France 245 high- and medium-pressure engines representing 2,584 h.p., and 45 low-pressure engines totalling 580 h.p. From 1784 to 1835, 1,448 steam engines, totalling 19,126 h.p., were constructed in France. The situation was the same in other Continental countries.

This constant increase in the number of engines and machines of various sorts necessitated larger works, better equipped for the construction of these engines. All the factories where the work had previously been carried out by hand now became works where manufacture was effected by machinery. Numerous new concerns were established. The methods of working had to be modified and improved to permit the construction of engines of an increasingly greater degree of perfection. All these changes occurred during the 30's and 40's of the last century. It may therefore be perfectly well stated that for a century we have been in the era of the construction of machines, and even to-day it is possible to find in all industrial countries a certain number of large engineering works which were established between 1830 and 1840, or mechanical engineering works which only reached their prime at that period.

At the time of the discovery of the steam engine, only one material, wood, was employed for constructions of all kinds. An endeavour was even made to construct steam engine cylinders of wood, but cast iron was very soon found to be an indispensable material for such cylinders. It was at first contended that it was necessary to find a natural material stronger than wood, but this mistake had very soon to be rectified.

The Pre-Steel Era

At that period, it was not possible to resort to steel which is so largely employed to-day in the construction of prime movers. It must in fact be remembered that at that time forgeable iron was only produced directly in puddling furnaces or in finery hearths by treating pig-iron on the hearth of a furnace heated by wood charcoal. The quantities produced in one operation were very small and very irregular in nature. Forging practice, which had already made considerable progress, only dealt with pieces of relatively small dimensions. It is true that the puddling process, discovered by Henry Cort in 1778, was known, but this process made very slow headway because the technical value of puddling depended solely on the skill of the workmen entrusted with the handling of the furnaces. During the first twenty years of the last century, only a very small number of puddling works were built on the Continent. Between 1830 and 1840, the puddling process spread but slowly, and it was only in 1840 that the art of producing steel also in the puddling furnace was learnt. Puddling works reached their zenith between 1850 and 1870, but later, with the advent of the Bessemer and Siemens-Martin processes, they gradually passed into the background.

It follows from the foregoing that the epoch at which the period of technical progress in cast iron commenced is perfectly well defined, and if statistics for the production of iron and steel at that period were available, it would be seen that the production of cast iron was larger than that of all classes of forgeable iron. It is of interest to the foundryman to know that a century ago cast iron had become the most important and the most frequently employed constructional material in engineering and had even supplanted steel.

Cast iron was employed not only for making the cylinders of steam engines, pumps and blowing engines, and in some special cases for replacing bronze castings, but it was also used for making almost all other engine parts: frames, beams, cranks and flywheels of the engines were made of cast iron, as were also the valve chests and slide bars. A cast iron steam boiler had even been made. We must not, however, lose sight of the fact that for a long time afterwards wood, sometimes reinforced by bands of wrought iron, was still used as a constructional material.

"Artistic Engines"

To meet the incessantly increasing demands, the foundry improved its technique of production—moulding in sand, the use of cores and strickling of the moulds were studied and utilised to an increasing extent. In order to satisfy the taste of the time, all machine and engine parts were given artistic forms as far as possible. It was the aim to utilise in steam engines all the styles customarily adopted in public edifices. As a result, moulding was complicated, but progress was made in its practice. This desire for artistic decoration affected castings employed in all spheres—decorative castings for buildings, railings, fencings, plates and artistic objects attained a high degree of perfection and beauty, and artistic iron founding developed to a point that has never been reached again since. The period of artistic engines lies approximately between 1830 and 1860. It was gradually replaced by a period in which the principal aim was simplicity of form and suitability of each casting for the intended purpose, and finally by the period in which lightness and the possibility of low manufacturing costs predominated.

Direct Casting from the Blast Furnace

At that period, foundries obtained the metal for their castings direct from the blast furnace. It was only to a minor extent that pig-iron and broken pieces of castings were remelted in the cupola. Unfortunately, there are no statistics available to show the proportion of each type of melting in the total production. It is, however, certain that the former was by far superior. The metal was taken in a ladle from the main runner of the blast furnace and poured into the nearest sand mould, or else a suitable runner through which the iron could run was provided between the tapping hole of the blast furnace and the mould. This method was employed for a long time in blast-furnace practice, and in some special cases, up to recent times, it has enabled very high production figures to be attained.

The products obtained by direct casting from the blast furnace were called direct metal castings, while those obtained from metal melted in the cupola were called remelt castings. These names are still to be found in the statistics of the 19th century. Thus, from 1880 to 1890, about 35,000 tons of direct metal castings were made in Germany, *i.e.*, about 6 per cent. of the total production of castings.

This close relationship between blast-furnace practice and foundry practice lasted for a considerable time, it may be said until the end of the last century, and it has therefore had a considerable influence on the history of cast iron.

Generally speaking, with the increasing number of applications, a higher mechanical strength and longer life had to be required of cast iron as a material which was difficult to replace in engineering construction. For example, with the advent of high-pressure engines, castings were subjected to severer conditions in service. Difficulties were encountered as soon as an attempt was made to cast blast-furnace iron in loam or sand moulds which had to be filled perfectly in all their parts. Frequent fractures of castings were recorded, causing lengthy stoppages of the engines and costly repairs. In railways, particularly, the number of serious fractures grew to such disquieting proportions that the use of cast iron was prohibited by some State organisations.

It was then that the user of castings imposed inspection conditions. At first, these conditions were very general, because they corresponded to the knowledge of the period, which gradually became better defined in two directions. Experience very soon showed that cast iron must be a

* Paper presented on behalf of the Technischer Hauptausschuss für Giessereiwesen to the Seventeenth Congress of the French Foundry Technical Association, held at Lyons.

material which is not very hard. It must have a grey structure in all parts of castings, even at the edges. Any white zone causes fragility and constitutes a source of incipient fracture. This necessity for a grey structure was strengthened by the fact that white cast iron could not be machined by the tools of that period. When an edge was hammered, therefore, the face of the hammer had to penetrate the metal but the casting had not to split or crack. The second piece of knowledge was that certain blast furnaces produced an iron very suitable for castings, while others produced a poor iron which was useless for casting in moulds. At that time, there were no machines for testing cast iron and the methods for the chemical analysis of cast iron had not been perfected, and consequently foundries did not make any tests or analyses.

Early Difficulties

The handling of the blast furnace offered very considerable difficulties for the workmen in charge of it. In small units with small daily productions, the use of cold blast or at first only slightly heated blast, and charges of irregular nature caused irregularities in operation and modifications in the thermal conduct of the blast furnace. The cast iron produced was of a widely varying quality. Sometimes very grey, it would become white again with numerous blow-holes. There were blast furnaces which could never produce iron of suitable composition. Before pouring each of his castings, the foundryman had to examine his iron, and as he had no technical means at his disposal for that purpose, he had learnt by daily observation to regard the surface play of his molten iron as a means of judging the quality of the latter. For a considerable time, this art played a great part in the development of cast iron. Some of the indications which the foundryman found on the surface of his metal may be summarised.

A hot metal with a high silicon content, then known by the name of "kishy" iron, after pouring in a sand mould has at first a uniformly brilliant, white surface. When cooling occurs, it is covered with a thin surface film which fissures here and there and slowly becomes continuous. A cast iron with a moderate silicon content exhibits a very rapid surface break, fissuring of the surface film occurs simultaneously in numerous places, the fissures rapidly close and fresh ones are immediately formed. A low silicon iron is very turbulent. It throws off sparks and liberates numerous gas bubbles. From the nature of the sparks—brilliant and sub-divided or spherical—it is possible to make additional deductions regarding the nature of the metal. Finally, during solidification, black or dark patches are formed on the surface of the metal, and from these also it is possible to judge the condition of the iron. This examination, based solely on practice, has not been surpassed in precision even by the use of modern means of control. The foundryman of former times who took his iron from the blast-furnace hearth, had a better knowledge of the nature of his iron than the technician of to-day, favoured with all the instruments of science.

Growth and Distribution of Foundries

With the growth of foundry practice, this art has gradually been lost. The number of foundries increased incessantly, and more and more of these foundries became independent of blast furnaces, and were established in regions where the demand for castings was greatest. Frequently, blast furnaces were shut down because they were uneconomical to operate or because they were at first supplied from an ore deposit which later became exhausted, while the foundries dependent upon these blast furnaces continued to operate, obtaining their supplies of iron from other countries. These foundries adopted the system of melting in the cupola, or in the reverberatory furnace, scrap castings together with pig-iron from other blast furnaces. This conversion of the foundries was favoured by the enormous development of the railways, which for the first time in history constituted a regular means of transport for heavy raw materials to every point where they were required. In addition to the independent foundries, there still remained for a considerable time some foundries operating in conjunction with a blast-furnace plant.

Designation by Fracture

The gradual separation of the foundry from the blast furnace obliged the foundryman to abandon the old practice of appreciating the quality of the iron according to the appearance of the surface. It was no longer necessary for the foundryman to concern himself about the nature of the charges or melting conditions of the blast furnace, but he had to take the iron as it was in the pigs supplied to him. In most cases, the appreciation of the metal according to the appearance of the surface was no longer utilised, because when the metal was remelted in the cupola it did not exhibit such distinct surface patterns as the metal from the blast furnace. It was, therefore, necessary to make use of other indications for appreciating the quality of the iron, and thus it was that the custom arose of judging pig-iron according to its fracture. During the whole of the second half of the last century, the appearance of the fracture played a considerable part in the grading, sale and definition of cast iron. The specimens were described by methods and expressions analogous to those normally employed in mineralogy for distinguishing minerals. It has never been possible, however, to define exactly the characteristics of the different sorts of cast iron from the appearance of the fracture.

Even when, between 1860 and 1870, the manufacture of steel had made considerable progress as the result of the discovery of the Bessemer process, it was still not possible to distinguish clearly between foundry irons and refinery irons. For example, towards 1875, the following description of pig-irons is found:—"Incompletely carburised pig-iron with a white fracture is unsuitable for any purpose. Irons saturated with carbon and having a white colour and a well-defined crystallisation known as specular iron are mainly suitable for the manufacture of steel in the puddling furnace or Bessemer converter. Ordinary white irons having a less perfect crystallisation can be used in the puddling furnace. Raw irons are suitable both for the Bessemer process and for the foundry, and irons with a grey fracture are destined for the foundry."

Another publication of the same period mentions the following as products of the blast furnace:—Specular iron, semi-specular iron and various pig-irons. The last group includes both grey iron and mottled and white irons. Later the size of the grain of the fracture was likewise distinguished. The "grain" became the principal feature of cast irons. By melting in the cupola a mixture of close-grain and open-grain irons in the proportions indicated by practice, iron suitable for any application could be produced. The grading of irons according to grain became increasingly common, and in England 20 to 30 sorts of pig-iron were distinguished, stocked and utilised in this way.

Competition from Steel

In the meantime, cast iron lost its leading position on the ferrous metals market to such an extent that, according to American statistics, the average price of pig-iron fell from 40 dollars in 1860 to 10 dollars in 1910. The new highly efficient methods of producing steel by the Bessemer and Siemens-Martin processes, the improvements in rolling practice and the extremely high qualities of steel resulted in cast iron being ousted from a certain number of important fields of application. For example, in 1878, out of a total production of 2,148,000 tons of pig-iron in Germany, only 5.2 per cent. was foundry iron, and in 1884 the percentage of foundry iron was 5.8. Steel occupied the first place in a large number of applications.

One example of the competition existing at that time between steel and cast iron may be mentioned. Originally, railway rails, after having been made for some time of wood, were made of cast iron. In some English price statistics dating from 1852 and covering 30 years, the price of steel rails was at first double that of cast-iron rails. In the course of time, however, the price of the former fell continuously, while the price of the latter was merely subject to slight variations depending on the circumstances. Finally, the price of steel rails, owing chiefly to their low weight, fell below that of cast-iron rails, and in 1880 the price of cast-iron rails is no longer quoted in the statistics. The position was the same in the case of numerous other applications. It can be said that from that period, cast iron has always occupied the second place relatively to steel and has lost one by one all its fields of application.

The appreciation of the quality of grey pig-irons according to the appearance of the fracture and the grain is quite uncertain, because it involves the personal element and depends upon the experience of the person making the examination. It was noticed that considerable errors could be made in this appreciation. When, for example, the method of applying chemical analysis became known, it was often found that an iron with 4 per cent. silicon had the same grain as an iron having about 1.8 per cent. silicon, and that coarse-grained irons could contain 2.5 to 3.5 per cent. silicon. Blast furnaces could influence the grain simply by modifying the character of the slag. All other things being equal, a coarser grain was obtained with a basic slag than with an acid slag. A factor which was still more important in the history of the development of the art was the knowledge of the more or less considerable influence exerted on the quality of the iron by the nature of the ores charged into the blast furnace. It is not immaterial whether a grey iron is produced by treating high-grade red ore or by reducing a poor ore of brown colour. This led to the adoption between 1860 and 1870 of the classification of pig-irons, according to the ores employed, into magnetite irons, red ore irons, brown ore irons with puddling slag and reheating slag, etc. English pig-irons were graded into all-mine, past-mine, hematite and cinder pigs.

Nomenclature

In this connection, the following point must be made plain:—In mineralogy, hematite is the name given to a mineral consisting of pure oxide of iron. In foundry practice, the name hematite is also given to a certain kind of pig-iron. This use of the same word for denoting two different materials finds its explanation in the history of the period. The original and correct designation was hematite pig, that is to say, pig produced from a red iron ore. When this original meaning of the word was later forgotten or ignored and a hematite was only defined according to the chemical analysis, the mistake was made of neglecting the character to which the term was originally applied, because the experience of the foundryman of early times, according to which a pig-iron produced from a red iron ore had quite a different nature from another produced from a brown iron ore, even if the chemical analysis indicated that the two irons had the same composition, must be admitted to be correct.

Between 1860 and 1870, every blast-furnace plant treated ore extracted from mines in the vicinity. Foreign ore was rarely used by blast furnaces. There were no appreciable variations in the composition of the ores employed, and consequently the nature of the iron produced was constant. For this reason, it became customary to refer to irons by the name of the blast furnaces which had produced them. This system of nomenclature was general and to some extent has been preserved up to the present time. To sum up, foundry practice had led to the designation of pig-irons, appreciated according to their suitability for each particular application, by the name of their country and sometimes their region of origin.

This system of nomenclature was justified as long as blast furnaces treated local ores, but when towards the commencement of the present century a large number of small blast furnaces supplied by ore deposits of small extent disappeared, while some blast-furnace plants grew in importance and had to employ ores from other regions, sometimes even from abroad, this system lost all its significance. The nature of the pig-irons altered whenever fresh ores came to be used.

This designation according to the country of origin did not in any way interfere with the grading of foundry irons according to the appearance of their fracture and grain, the terminology according to the country of origin being merely a sort of supplementary designation. The appearance of the fracture was represented by numbers which were not the same in every locality. The following example corresponds to the practice prevailing between 1890 and 1900: No 1 grey iron has a very coarse grain and a very low hardness. No 2 iron has a more compact, closer grain, is harder and has a greater strength than the preceding iron. No 3 is still harder, and the colour of its fracture is grey tinged with white. Nos. 4 and 5 irons are mottled, in other words their fracture exhibits a mixture of grey iron and white iron, grey predominating in No. 4 iron and white in No. 5 iron. No. 6 iron is entirely white. Later, this notation was replaced by classification according to chemical analysis, but it is still in use at the present time.

Beginnings of Chemical Analysis

The methods of chemical analysis had first of all to be thoroughly perfected before its results could be used for providing information regarding the nature of pig-irons. Between 1850 and 1860, pig-irons were already being analysed in scientific laboratories, but so far it had not been possible to deduce conclusions of practical use. Between 1860 and 1870, the number of analyses made became very considerable, but it was not until after 1880 that the methods of analysis were perfected which, after some slight unimportant modifications, were to be employed in works' laboratories.

If the analyses of the pig-irons produced at that period are compared with those of modern irons, it is noticed that the earlier irons had a much lower carbon content, *viz.*, 2 to 3 per cent., and that the irons produced in the blast furnace heated by coke had a much higher sulphur content., *viz.*, 0.3 per cent., and an even higher sulphur content was not uncommon. In some cases, the irons of that period had a high manganese content capable of attaining 1.5 per cent.

The application of chemical analysis, which had now become current, to the investigation of cast iron rapidly extended the knowledge of this material. As long as the proportions were uncertain, there had been doubt in deciding certain points such as: Should specular iron contain manganese as an essential element? or: Is carbon or silicon the principal element? It was only at the commencement of the 20th century, however, that investigations were made which enabled certain conclusions to be drawn regarding the influence of each of the elements contained in cast iron on the properties, quality and also the "life" of the iron. From that period, the classification of the types of pig-irons has been effected according to the chemical analysis and mainly according to the silicon content, followed by their classification according to the phosphorus content. That is the basis on which the pig-iron market has been organised in every country, and this basis is still used at the present time.

Inherent Properties

Nowadays, however, this common classification by chemical analysis is no longer adequate from the technical point of view, because the foundryman has been taught by experience that the quality of an iron does not depend solely upon its chemical composition, but also upon its previous history, according to the nature of the ore, fluxes and coke employed in the blast furnace and the capacity of production of the furnace, the temperature of the blast and other working conditions. All these matters are very familiar to the foundryman, who is well aware that an iron from one blast furnace may possess very different qualities from those of another iron having exactly the same chemical composition, but originating from another blast furnace. Unfortunately, it is not yet possible to express all these factors in terms of numerical relationships, and until this difficulty has been surmounted, there is no reason to modify in any way the conditions of sale of the pig-iron market.

From the period under consideration the situation in the foundry has developed in various respects. First of all, the large blast furnaces have found it impossible to satisfy the demands of a foundry of even relatively slight importance. Furthermore, the remelting of broken castings has assumed an ever-increasing significance, reducing the proportion of pig-iron in the charges for the production of foundry iron. This situation has caused modern foundries to regard the product obtained from a mixture of pig-iron and scrap cast iron as a crude alloy and to discover treatments for making refined cast iron.

The investigations made in this direction during the last twenty years have already furnished results of great value, but they are still far from having exhausted the subject. At the present time, the mode of solidification of cast iron can be influenced by appropriate means so as to obtain castings of high quality. Among these cast irons, it is possible to mention those known by the name of high-duty irons, special cast irons improved by additions of heavy metals and those subjected to superheating or to a treatment for producing in the bath inclusions of foreign bodies acting as nuclei for the fine crystallisation of the graphite. It is probably on the basis of this treatment that the solution of the whole problem of regulating the process of solidification will be found. Since, as shown by certain publications, a structure imparting excellent qualities to cast iron can now be produced by melting an ordinary foundry iron mixture under a suitable slag or by the addition of alloys containing titanium, as shown by Norbury, it is to be hoped that a quantitative explanation of the action of such treatments will shortly be forthcoming.

Complexity of Cast Iron

Another difficulty is still encountered when it is desired to express numerically what exists in the field of cast iron in the diagram of the iron-carbon system. In this field of the binary system, matters are much more complicated than in that of simple carbon steels. In this latter field there are, at least under ordinary conditions, only two constituents: ferrite and pearlite, and there exists between the quantities of these constituents a simple ratio, depending upon the carbon content. The variations in the quality of the steel are merely dependent upon the relative proportions of these two constituents. In the high-carbon alloys represented by cast irons there may be four structural constituents: cementite, graphite, pearlite and ferrite, and the iron-carbon equilibrium diagram fails to provide any indication regarding the proportions of these constituents in terms of the thermal conditions. In particular, it is impossible to ascertain from this diagram how much carbon is in the form of carbide and how much in the form of graphite of primary formation. Hitherto, a stable system and a metastable system have always been shown in the iron-carbon diagram, despite the fact that in numerous cases solidification does not take place in one system or the other but in a state intermediate between those corresponding to the two systems. This state of affairs impedes the growth of our knowledge of cast iron and calls for further investigation.

If it be supposed, for instance, that the primary graphite comes from the decomposition of carbide, it is produced according to a process expressed by the equation $Fe_3C = 3Fe + C$, which is an equilibrium equation in the range of temperature to be taken into consideration in the case with which we are concerned. In the scope of the above supposition, it would be more correct to establish a ternary diagram with the three components Fe – Fe_3C – C. The lines of the stable and unstable systems of the diagram which are available at present would be projections on a plane, the position of which in space is indefinite.

It is to be hoped that investigations will shortly throw light on all these points and will make it possible to establish firm bases for a final classification of cast irons. Untiring research work has, indeed, already enabled the constitution of cast iron to be made clear enough for the foundryman to derive the maximum benefit from the melting furnaces at his disposal.

As the above examination shows, the methods of distinguishing pig-irons have undergone frequent changes, which may be represented as follows, of course with more or less considerable periods of overlap:—From 1830 to 1860, according to the "break" on the molten iron; from 1840 to 1900, according to the appearance of the fracture and grain; from 1860 to 1910, according to the blast furnaces of origin; from 1900, according to chemical analysis. In the course of the past few years, it has been possible by suitable treatments during melting to produce structures which do not in any way resemble that of the metal as used.

Publication Received

The Institution of Mechanical Engineers: Brief Subject and Author Index of Papers in the Proceedings, 1847-1937. Published by the Institution, Storey's Gate, London, S.W.1.

It must not be thought, because during the 90 odd years of its existence the Institution has only had about a dozen Papers presented to it on foundry practice, that its Council has not been sympathetic to the general question of the main raw materials of the industry it serves. From the year 1890 onwards it has sponsored research into alloys, and up to now eleven reports have been presented by such eminent authorities as the late Sir William C. Roberts-Austen; Sir Harold Carpenter; Sir Robert Hadfield, and the late Dr. Rosenhain. These are classical contributions to the knowledge of metallurgy, and many of the phases dealt with relate to foundry products. It takes 160 pages to cover the subject and name index, and the compiler, Mr. Alfred R. Stock, the Institution's librarian, is to be congratulated on the arrangement he has chosen, as it is extremely easy to find any reference sought.

Special Areas in England and Wales

Up to the end of July, 1938, offers of contributions towards rent, rates and income tax had been made to 62 industrial undertakings to induce them to set up factories in the Special Areas of England and Wales, and further negotiations were in progress. On the Team Valley Trading Estate, near Gateshead, 68 factories had been completed up to the end of July, 64 being occupied and employing 1,568 people. Tenants had been obtained for 41 further factories of which 30 were under construction. On the South Wales Trading Estate, at Treforest, 22 factories were occupied at the end of July, giving employment to 459 people. Two factories had been built at Maryport, and progress had been made with the preliminary arrangements for the repairs to Maryport Harbour. Improvement works to Whitehaven Harbour were proceeding. The Commissioner's total commitments at the end of July, 1938, in respect of all the Special Areas in England and Wales were £16,358,000, including grants to assist industry of £5,111,000.

Budgetary Control and Standard Costs

II.—REPETITION FOUNDRIES AND THE BUDGET

By T. McALPINE

(*Continued from page* 138.)

Coreshop Budget

Form 6 illustrates a form of budget suitable for a coreshop. "Material" refers to all material which can be directly charged against pattern numbers. Any material which cannot be charged direct is included in the oncost of the department. Oncost can be applied on the same basis as adopted in the loose-pattern moulding section.

PRODUCTION AND COST BUDGET FOR YEAR ENDING 19 .

Product.....*List of Castings.* *Coreshop Department.*

No. off.	Patt. No.	Description.	No. per set.	Class of core.	Material cost. Unit.	Material cost. Total.	Labour cost. Unit.	Labour cost. Total.	Oncost. Unit.	Oncost. Total.	Final cost. Unit.	Final cost. Total.	Per set.

Form. 6.—*Production and Cost Budget for Coreshops.*

Plant and Equipment Budget

The primary objects of this budget are to show the management:—(*a*) The expenditure to be incurred in installing new plant, machinery, structures, etc.; (*b*) the money to be spent in regular upkeep of plant, machinery and structures; (*c*) the number of men required in each department to carry out this work—this information is required for the payroll budget, and (*d*) the money to be spent in purchasing the materials required to carry out the work. If this material can be detailed to show the quantity to be used of each kind then it will be possible to prepare a purchases budget.

There are several sections to this budget and several departments which carry out work in connection with it, as follows:—

(1) Repairs and Maintenance Department. (*a*) Installing new plant, machinery, equipment, etc., and erecting structures, and (*b*) repairs and maintenance of plant, machinery, etc.

(2) Productive Departments. Making new tools such as moulding boxes, coreboxes, etc.

(3) Purchases of new tools, for example, chisels, grindstones, hammers, etc.

(4) Wood Patternshop. (*a*) Making new patterns and coreboxes, and (*b*) repairs and maintenance of patterns and coreboxes.

(5) Metal Patternshop. (*a*) Making new patterns and coreboxes, and (*b*) repairs and maintenance of patterns and coreboxes.

The production budget will provide a basis for deciding the additions to be made to plant, machinery, equipment and patterns. In preparing this budget it will be necessary to estimate the material and labour cost of each pattern and the production cost, or purchase price, plus installation cost of each machine and equipment item.

If detailed estimates are not possible or practicable then the management should fix a maximum amount to cover additions to plant and equipment, and for making new patterns, and then control should be exercised to ensure that money spent does not exceed this maximum figure. Money spent on new patterns and plant and equipment would be capitalised and, therefore, would not be a charge to costs except for a small proportion to be written off as a depreciation charge.

Tools enter the same category except for certain items that cannot be treated this way, for example, chisels, small grindstones, hammers, files, etc., which are generally included in departmental expenses as, and when, they are issued from stores. Repairs and maintenance of patterns, plant and equipment, etc., can generally be estimated satisfactorily with the aid of cost records relating to previous periods. The distribution of repairs and maintenance expense to the various departments will be based on the probable benefits which each will derive from this service, and previous cost records can provide a good guide for apportionment.

CUPOLA PRODUCTION BUDGET FOR YEAR ENDING 19 .

Details.	Loose pattern moulding. Per cent.	Loose pattern moulding. T. C. Q. Lbs.	Continuous casting plant. Per cent.	Continuous casting plant. T. C. Q. Lbs.	Total. Per cent.	Total. T. C. Q. Lbs.
Loose pattern moulding budget ..						
Continuous casting plant budget ..						
Plant and equipment budget ..						
Plus allowance for "spills" and metal "pigged" in shops ..						
Metal to be supplied to moulding shops						
Plus allowance for cupola overmelt						
Plus allowance for melting loss ..						
Total metal charge to cupola ..						

Form 7.—*Section* 1.

CUPOLA COST BUDGET FOR YEAR ENDING 19 .

Details.	T. C. Q. Lbs.	T. C. Q. Lbs.	Price per ton.	Amount.
Virgin metal				
Back scrap				
Alloys				
Melting materials:—				
Coke				
Ganister				
Limestone				
Cupola labour				
Cupola oncost				
Laboratory expenses				
Cost of melt				
Less melting loss				
Less cupola overmelt				
Cost of metal delivered to moulding shops				
Cost per ton				

Form 7.—*Section* 2.

CUPOLA COST BUDGET FOR YEAR ENDING 19 .—*Continued.*

Details.	Loose pattern moulding. T. C. Q. Lbs.	Loose pattern moulding. £ s. d.	Continuous casting plant. T. C. Q. Lbs.	Continuous casting plant. £ s. d.
Metal ex-cupola				
Less metal pigged, etc. (at scrap value)				
Cost of metal poured into moulds ..				
Cost per ton				

Form 7.—*Section* 3.

Cupola Budget

The starting point of this budget is the total weight of rough castings to be produced, as shown by the production budgets, and the plant and equipment budget. This weight must be increased to allow for defective castings, metal spilt in the shops, and metal "pigged" because of its unsuitability for pouring, etc. The total obtained at this stage represents the weight of metal to be supplied to the shops, and when cupola overmelt and melting loss (a weight based on past experience) are added the resultant figure gives the weight of metal to be supplied to the cupola.

The next step is to ascertain the cost of production, and as the various metals and the quantity of each required for the mixture can be readily ascertained, this should be comparatively simple. Where several different mixes are used, a separate production and cost budget should be made out for each mix.

The price taken for each metal should not be subject to much variation throughout a year, as it is usual for most foundries to place long period contracts for metal supplies.

Form 7 gives an illustration of a cupola production and cost budget.

(*To be continued.*)

Non-Destructive Testing by Gamma Rays

By J. G. HALL

The increasing rigidity of specifications for cast and assembled parts, together with rising costs both of labour and materials, has drawn increased attention to the possibilities and practicability of non-destructive testing. The necessary adoption of methods other than visual inspection, in order to determine the possible existence of internal defects, has resulted in the application of radiography to this end. While the practice of radiography by means of X-rays has already obtained a relatively wide vogue, and in some directions may be said to have achieved spectacular results, there remains a further method which, although by no means so widely known, is of particular interest because of its freedom from certain limitations which have acted as obstacles to the wider application of X-rays.

Differences Between X-Rays and Gamma Rays

Gamma rays, the essential feature of gamma radiography, are produced in the disintegration of radium, and offer a number of distinct advantages. Whereas the limit for the practical use of X-rays for testing purposes is in the region of 4 in. of steel, gamma rays have been found effective up to 10 in., with a possible extension to 12 in. X-ray equipment is bulky, has a large depreciation factor and is not really portable, being practically anchored to a source of high-voltage electricity. Gamma rays suffer from none of these disadvantages—a capsule of less than $\frac{1}{4}$ in. dia. contains enough radio-active substance for the examination of any commercial object—is easily transportable, has no complicated machinery, and does not need the services of an expert electrician. The foregoing claims may appear to create an impression that gamma rays are on the point of superseding X-rays as the most effective medium for industrial radiography, but such is not the case. Rather should the two processes be considered as supplementary to each other, the value of the one becoming apparent where the scope of the other ceases. The use of X-rays as a testing medium dates as far back as 1912, with a marked development in 1922 with the advent of high-voltage valves and exciting equipment; it was not until 1930 that the practicability of gamma radiography for the examination of thin and thick metal sections was effectively demonstrated, and since that date a number of applications to routine testing have been successfully carried out.

Apparatus and Methods

The apparatus and methods for gamma radiography are very simple. A small container of radio-active material, radium sulphate sealed in small silver capsules, is supported rigidly in front of the object to be inspected, and X-ray films in light-tight holders are fastened to the back of the object. Rays passing through the object cause a shadowgraph to appear on the film similar to those obtained with X-rays. Recommended films include the Eastman Ultra Speed Duplitised X-ray film, which is of large grain size and double emulsion, and the new Du Pont X-ray film with a comparable speed possesses the added advantage that it cannot be over-developed. A slower film, Radiatised dental film, is used when irregular sections are to be radiographed at one time. In order to shorten the time of exposure intensifying screens are used, the German make known as "Supra Sinegram" or extra thick calcium tungstate screens being found most satisfactory. Two screens are used for each film, one in front, one behind. Should a longer exposure be permissible, lead foil, say G.E.C. X-ray foil 0.006 in. thick, may be substituted for the screens. In all radiographic tests it is advisable to use duplicate films. The advantages accruing from this practice include the averaging out of irregularities in the emulsions originating from manufacturing processes, and increased confidence in the interpretation of faint markings caused by small defects. The arrangement advised when using a pair of films is: lead—film—lead—film—lead. In this manner the films are separated only by the thickness of one lead sheet, and are contained in a single exposure holder. Variations from this practice lay open the road to a multitude of troubles, such as the appearance of spurious marks from the exposure holder.

Influence of Distance

It will be appreciated that the relative positions of the object to be examined and the radio-active source must have a very marked effect on the results obtained. Should minute flaws such as those in welds need to be detected, the distance from the radio-active source to the films behind the object must be as great as possible and the actual size of the radio-active source as small as practicable. Since the time of exposure increases as the square of the distance from source to film it will be apparent that the choice of distance will be influenced by the time factor. If relatively gross flaws only are sought the distance may be made short, *e.g.*, a hole $1\frac{1}{2}$ in. deep and 3 in. in diameter in a block of steel 10 in. thick will be revealed at a distance of 12 in.

The depth of defect in the direction of the ray can be determined in the following ways: (1) Measurement of film blackening and comparison with a thickness blackening calibration made on the same film; (2) comparison of two radiographs taken with rays passing through the specimen at different angles; (3) comparison of two images on the same radiograph, made by taking successive pictures with the rays passing through the specimen at different angles and striking the film, and (4) viewing stereoscopically two radiographs taken independently with a proper displacement of the radium between exposures. The last three methods call for two exposures and take twice as long as an ordinary radiograph; consequently, the first is most generally used, and will be further discussed here.

Density Considerations

The density of a radiographic film depends not only on the thickness and density of the metal penetrated, but also on the exact exposure and technique of development and even on the exact film emulsion itself. It is therefore impossible to tell directly from the film blackening alone the thickness of a defect, this being estimated by comparison of the blackening at the defect with that through a known thickness of metal. Densities at defects may be measured on a densitometer and compared with densities corresponding to known thicknesses of the specimen on the same film, and a curve may be plotted of density against thickness for the given film, from which it is easy to read off thicknesses corresponding to the densities at the defects.

While the methods outlined are neither difficult nor lengthy when the requisite apparatus is available, adequate information can frequently be gained by simple estimation with the eye. Experience in the comparison of radiographic markings with actual physical examination of the sectioned specimens will be found most helpful in attaining a satisfactory standard of estimation by the naked eye.

Time-Temperature Method

The method of development is similar to that used in ordinary X-ray work, being carried out in tanks and having as its outstanding difference the addition of 20 milligrams of potassium iodide to each litre of developing solution. This has the effect of reducing the amount of chemical fog and permitting a longer developing time, increasing in this manner the contrast of the radiograph and at the same time decreasing the exposure required. The time-temperature method of development as outlined in Table I should be followed except in those cases in which over-exposure is to be feared. Every care should be taken that the films do not touch each other or the sides of the tank during development. Frequent agitation will also be found useful in order to obtain even development. Films should be washed in running water for 15 to 30 secs. before being placed in the fixing bath, as this will increase the life of the fixer and the speed of the reaction. In hot weather the use of a hardening solution between the developing and fixing baths is advisable. Hardening is effected by agitating the films in the hardening bath for one minute, allowing them to remain in the bath for a further two minutes and then proceeding with the fixing.

TABLE I.—*Development Times.*

Temp. of bath. Deg. F.	Normal development. Mins.	Over-development. Mins.
55	8.5	17
60	6.75	13.5
65*	5.0	10.0
70	4.0	8.0
75	3.0	6.0
80	2.0	4.0

* Recommended.

As in all photographic work, the fixing should continue for a time equal to twice that required to "clear" the film, which should then be washed in running water for a period of 15 min. and before hanging up to dry should be wiped very carefully with a wet camel-hair brush or a piece of wet cotton-wool, in order to obviate the appearance of streaks when dry. Such streaks, which may be due to hard water or the presence of compounds deposited by the hardening process already mentioned, might by their presence lead to no small difficulty in the interpretation of the finished radiographs.

Recommended hardening, developing and fixing solutions are as listed below:—

Developing Solution.—Eastman's X-ray developing powders or their equivalent mixed with water in accordance with the directions furnished by the makers. To this solution add 20 milligrams per litre of potassium iodide.

Hardener.—Thirty grams of chromium potassium sulphate (chrome alum) per litre of water.

Fixing Powder.—Eastman's X-ray package for five gallons is recommended.

Interpretation

The most satisfactory method of reading films is through a viewing cabinet as used in hospitals. Another and simpler method of viewing films is to lay them upon a sheet of white paper. In this manner the light passes through the film once on its downward course, and again after it is reflected from the surface of the paper to the eye, thus accentuating the contrast.

Radiographic films provide an indication not only of interior defects but also of surface faults and irregularities, a property which in general is to be welcomed, as these superficial faults may function as markers in order to locate the exact position of interior defects. There are occasions, however, when it is desirable so to contrive conditions that internal defects only are registered. The most satisfactory method of eliminating surface markings is to coat the specimen with a mixture of litharge and glycerine in the form of a thick paste, which mixture must be applied as soon as made owing to its quick setting properties.

Economic Considerations

From an economic standpoint it is always well to examine as much material as possible with the single radio-active source when once this has been arranged and adjusted for operation. At times, therefore, it is possible and convenient to arrange a number of articles in order that they may be radiographed simultaneously. When this is done, it is, of course, necessary suitably to arrange the specimens in relation to the radio-active source that the exposure may be correct for each individual article. Fig. 1 provides a characteristic placing for radiographing four articles at once.

Radium emits alpha, beta and gamma rays, all of which are inimical to the health of the workers, and call for special care. With respect

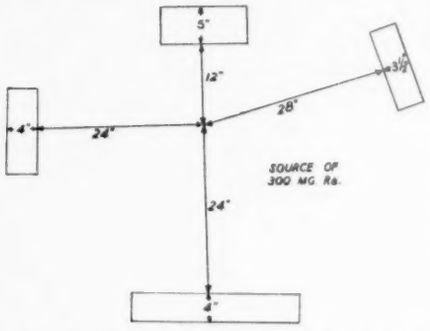

FIG. 1.—ARRANGEMENT FOR SIMULTANEOUS RADIOGRAPHING OF FOUR ARTICLES.

to the first two, the normal practice of enclosing the glass capsule containing the radium or radium salt in a thin steel cover provides adequate protection against all but the gamma rays, so that protective measures of a special nature are only called for against these. Radium should be stored in a safe of solid lead of some 6 in. thickness in all directions, should only be handled with tongs or strings, and never touched directly with the hands and should not be approached nearer than a distance of 10 ft. unless shielded by heavy castings. It should be borne in mind that human danger is directly proportional to the length of time exposed and to the intensity of the rays at that place. Thus, when it may be necessary to approach within a few feet of the

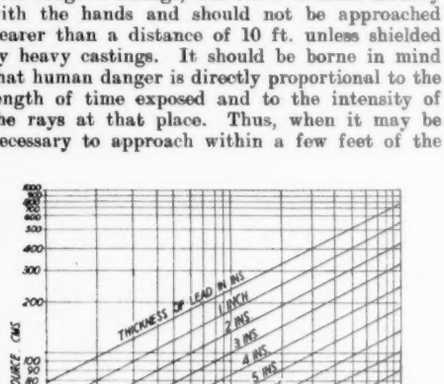

FIG. 2.—RADIUM PROTECTION CURVES.

radium in order to perform some essential operation, the danger may be kept at a minimum by remaining there as short a time as possible. A League of Nations Committee on Radium Protection has entered very fully into the question of adequate protection during working hours, and Fig. 2 from this source shows the various thicknesses of lead necessary to protect the operator at given distances from various quantities of radium. The basis of these figures is an 8-hr. day, reckoning 300 days to the year.

(*Concluded in next column.*)

Tar-Distillation Plant

USE OF NICKEL CAST IRON

Recent investigations into the causes and prevention of corrosion of tar stills have shown that costs can be reduced by the use of alloys which will resist attack to a better degree than the mild steel commonly employed for stills. The Annual Report of the Department of Scientific and Industrial Research, for instance, states that as a result of a series of tests on selected materials and alloys, nickel and nickel alloys were found to give good resistance to the action of corrosive constituents.

In that connection the data obtained by the South Staffordshire Mond Gas Company, Dudley Port, Staffs, during the examination of a still, are of interest. The process of distillation at Dudley is continuous, and three horizontal stills are operated in series. The first operates at about 220 deg. C. and is used for removing water and a fraction of the light oils. The second operates at 300 deg. C. and removes the bulk of the resinols, whilst the third still operates at 270 deg. C. with steam injection. The heaviest corrosion is always experienced in the bottom half of No. 2 still, and it is here that the employment of special materials has proved to be of the greatest benefit.

The tar used by the South Staffordshire Mond Gas Company is of the "low-temperature" type, but it is stated that it is a good deal more corrosive to mild steel than either the vertical retort tars or the low-temperature tars referred to in the D.S.I.R. Report. When mild steel was employed for the bottom half of No. 2 still, the average life corresponded to a throughput of 600 tons. Failure was due to general corrosion, which led to thin areas and ultimately to perforation.

Trials were made with various materials, and in some cases improved results were obtained. It was shown, however, that the increased cost of these materials had not brought about a sufficient reduction in operating cost to warrant their whole-time adoption. As a final experiment, Nicrosilal was utilised for the bottom section of No. 2 still, and the results have more than justified the choice of this material. The Nicrosilal employed was a cast iron containing 20-per cent. nickel, 2-per cent. chromium, and 4.5 to 5.0-per cent. silicon. When cleaned out recently, the lower half of the still had already dealt with 13,350 tons, and no appreciable corrosion was revealed.

The mild steel upper half of the still, which is not subjected to such severe attack, has been in use for a considerably shorter period than the lower half. It is heavily seamed, particularly near the joints with the lower portion, while the Nicrosilal was almost unaffected.

Despite the heavier first cost of the Nicrosilal section, the greatly-increased life and low maintenance charges have enabled a reduction in the processing cost of no less than 6.6d. per ton to be obtained. This reduction is compared with the figure obtained when the whole still was made from mild steel.

(*Concluded from previous column.*)

On a 24-hr. day basis, reckoning 250 days operation to the year, and using the services of an observer and a labourer, a cost figure of 12s. 6d. per hr. has been arrived at, together with a total cost of under one penny per lb. of metal tested. It would appear, therefore, that there exists a considerable field for the employment of gamma radiography, particularly in those cases in which this type of non-destructive testing may result in the abandonment of expensive machining processes on pieces of metal which are proved to be below specification standard, and where from considerations of human safety or equally weighty reasons the assurance of absolute soundness is essential.

Refractories for Induction Furnaces

FREDERICO GIOLITTI, in the course of a communication to a recent issue of "Metal Progress," states that comparatively little information has yet been published in Europe concerning the practical operation of steel furnaces of the coreless-induction type. A survey of published data, supplemented by private information, gives the impression that really standardised practices have not yet been established. This last fact may, perhaps, account for the widely-different opinions concerning the utility of this type of furnace for different classes of steels.

Obviously, the widely-differing types of electrical equipment used in the different plants may have only a very limited influence on the metallurgical results—with the exception, perhaps, of the different frequencies of current. However, the influence of this last element must be confined to the electrical and thermal efficiency of the system, and therefore can only affect the economy of production. The claim, often repeated, that current frequency may have an indirect influence on the metallurgical processes through its influence on the circulation in the molten bath, does not seem to be confirmed by the actual results in practice.

Quality of refractory lining seems to influence the quality of products to a much greater extent in the case of induction furnaces than with other types of furnaces. To substantiate this is the fact, acknowledged by practically all European plants, that good transverse elongations and impact resistances are difficult to obtain with steel from acid induction furnaces.

Many explanations have been offered for this fact, mostly based on the different ratio of temperatures of slag and metal in induction furnaces, when compared with the temperatures prevailing in all other types of furnaces. The practical consequence is that acid linings in European induction furnaces are almost wholly confined to the manufacture of tool steels.

Basic Linings

Some difficulties were experienced, in the beginning, in obtaining a good basic lining. In some plants, especially in France and Germany, the old process is still used. This consists of a strongly-rammed basic mixture, containing a certain proportion of clay (as a binding agent) and the quantity of water necessary to give a sufficient plasticity to the mixture. The rammed lining is then simply dried before receiving the first charge.

This very economical procedure has gradually been replaced by others, more expensive, but securing a better lining, as far as resistance to heat, shock and scour is concerned. In these processes the refractory granular mixture is used dry, and only lightly rammed around a metallic form. The latter is then heated gradually by induction, and melted. Under such conditions the lining is gradually and thoroughly baked, and the high proportions of binding materials can be avoided. A special refractory material containing alumina and zirconium oxide has been adopted by many steelworks, and gives excellent results.

The number of heats obtained in Europe with a basic lining varies, naturally, within wide limits, according to the raw materials used, the type of furnace, the quality of steel manufactured, and other factors. But under the more common conditions, 150 to 200 heats are considered a good campaign. A heat will generally take from 2 to 3 hrs. in furnaces of 4 to 8 tons capacity. As a consequence of the improvements in the preparation of basic linings, larger sizes (up to 12 tons) have been recently installed in a few plants.

Gases and Metals*

By COLIN J. SMITHELLS, M.C., D.Sc.

The discovery that certain metals were permeable to hydrogen led Graham in 1866 to study the absorption of hydrogen by palladium. He found that palladium foil that had been heated *in vacuo* would absorb large quantities of hydrogen at ordinary temperatures, and over 900 times its own volume when heated in the gas. Graham introduced the word occlusion to describe the shutting-up of gas in the metal in this way, but it is now more usual to speak of absorption, or simply solution. The palladium-hydrogen system is an exceptional one, for not only is the solubility much higher than for most gas-metal systems, but it also varies in an abnormal manner with temperature and pressure. Very little attention was paid to other systems until about twenty years ago, and even now the work in this field is confined to one or two laboratories which have specialised in the subject.

Existing knowledge of the solubilities of gases in metals is derived partly from direct, and partly from indirect, observations. The direct observations consist in measuring the amount of gas absorbed by a known weight of metal under definite conditions of temperature and pressure. The work of Sieverts and his school is far the most important in this field, and during the last twenty-five years a very large number of gas-metal systems have been carefully investigated at Jena. Similar methods have been used in a few instances by other workers. Mention may be made of the work of Röntgen and his colleagues on aluminium, and a number of contributions from the National Physical Laboratory.

Indirect information on solubility has been furnished in a number of ways. It has been shown that gases can diffuse through metals, and that to do so they must become dissociated at the metal surface. Diffusion is caused by differences in concentration at different points in the metal, and therefore whenever diffusion can be detected there is justification in assuming that there must be some solubility. The diffusion experiments help materially in understanding how the gas is distributed in the metal in different cases.

More important, perhaps, are measurements of the quantity and composition of gases which can be extracted from commercial metals. When heated *in vacuo* they give up considerable quantities of gas, which can be pumped away and analysed. The gas usually consists of mixtures of hydrogen, nitrogen, oxides of carbon and water vapour in various proportions. Sometimes hydrocarbons or sulphur dioxide are also found. These gases may not necessarily have been present in solution in the metal, and caution is necessary in drawing conclusions from these results.

Gases may be present in a piece of metal in four ways:—(*a*) As surface gas; (*b*) blowholes; (*c*) true solution, and (*d*) in combination.

Gas absorbed in the surface, although often of importance, is certainly not in solution. It is important to recognise that a great deal of the gas found by analysis may arise in this way, and it must be carefully distinguished from gas inside the metal. Gas found in blowholes may have arrived there in a number of ways, and its origin is of very practical significance. Although in some cases this gas may have been originally in solution in the metal, it must be considered as held only mechanically. It is the gases in true solution or in combination with the metal that are now to be dealt with.

* Being the Third Lecture of this year's Cantor Lectures of the Royal Society of Arts.

Gas in Solution or Combination

The gas absorbed by a metal may be dissociated and distributed as atoms throughout the metal lattice. This may be described as a simple solid solution closely analogous to the solution of one metal in another. It is necessary to consider whether in such a solution the gas atoms replace the metal atoms in the lattice, as in metallic solid solutions, or whether they exist in the spaces between the metal atoms.

A gas may be absorbed by a metal with the formation of a definite compound, or it may be in true solution at one temperature, but form a compound if the temperature is changed. For example, oxygen dissolves readily in molten copper, but as soon as the metal freezes cuprous oxide is formed and can be observed under the microscope as a definite phase. In solid copper the bulk of the oxygen is therefore no longer in true solution in the metal, although if the metal is heated *in vacuo* at 1,000 deg. C. the whole of the oxygen can eventually be pumped away, since cuprous oxide has an appreciable dissociation pressure at this temperature.

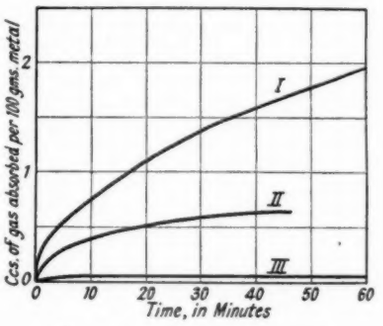

FIG. 1.—RATE OF SOLUTION.

I, N_2 in Aluminium at 800 deg. C., 760 mm.
II, O_2 in Silver at 280 deg. C., 336 mm.
III, H_2 in Silver at 700 deg. C., 100 mm.

Experimental Methods

The direct determination of solubility is usually made by exposing a weighed sample of metal to the gas at a known pressure and temperature until equilibrium is attained, and noting the volume of gas absorbed. In principle this is precisely the same as the method used in the measurement of adsorption. It is far more difficult, however, to obtain accurate measurements in the case of solution, for a number of reasons. In the first place it is necessary to distinguish carefully between solution and adsorption. Solubilities are usually small, seldom exceeding a few cubic centimetres of gas per 100 grams of metal, whereas the amount adsorbed on the surface, in the case of metal powders, may be many times as great. It is desirable, therefore, to reduce the ratio of surface to volume of the specimen as far as possible. On the other hand, owing to the slow rate of the diffusion process it takes a very long time to reach equilibrium with samples of metal of appreciable thickness, and there is a great temptation to use metal in the form of thin foil or powder for this reason. Equilibrium, except at high temperatures, is attained so slowly that many days may be required for each observation. Accurate results have only been obtained by very careful design of the apparatus and the use of modern high-vacuum technique.

Apparatus and Method of Measurement

The form of apparatus usually employed is essentially that of Sieverts and is in principle very simple. The metal is contained in a bulb of known capacity, which is connected to a vacuum pump, and also to a manometer and gas reservoir. The bulb is evacuated and a quantity of gas measured in the manometer is admitted to it. At any temperature the pressure in the bulb can be calculated from the gas laws, and any deviation from the expected value is due to absorption or evolution of gas by the metal.

After the degassing is complete, a measured quantity of gas is admitted to the reaction tube, and the temperature and pressure held constant until equilibrium is reached. It is obviously of the utmost importance to ensure that this is actually the case. The time required varies with the particular systems, the form of the sample and the temperature. Solubility generally increases with temperature and is often only measurable above the melting-point of the metal, at temperatures that necessitate the use of silica or other refractory material for the apparatus. These materials are not entirely impervious to gases, and may be attacked by the metal at high temperatures. Equilibrium is reached much more rapidly above the melting-point than with solid metal. In the case of molten metals, a few minutes may suffice. Some typical absorption time curves are shown in Fig. 1. At temperatures as low as 200 deg. C. many days may be required to reach saturation.

The only satisfactory method of ensuring accuracy is to approach equilibrium from both higher and lower pressures, that is by absorption and by desorption. Only when the values obtained by both procedures are substantially the same can one be certain that equilibrium has been reached.

Certain metals absorb appreciable quantities of hydrogen when made the cathode in an electrolytic cell, and Graham's pioneer investigations of the absorption of hydrogen by palladium were carried out in this way. At the beginning of electrolysis practically no hydrogen is evolved, but it is absorbed by the metal, and only when the metal is saturated does evolution begin. The method is restricted to the very limited range of temperature in which aqueous solutions can be used, and the results are not directly comparable with ordinary measurements since the pressure, or concentration of gas at the metal surface, cannot be expressed in terms of gas pressure. It has, nevertheless, definite advantages for certain types of investigation. In measuring solubilities with molecular gas it is seldom possible to determine when equilibrium has been reached at temperatures below 200 deg. C., owing to the excessive time required. The nascent hydrogen produced by electrolysis diffuses through the metal surface far more rapidly, and this difficulty is overcome.

Of the common gases, hydrogen is the most readily soluble in a large number of metals. Oxygen, although showing simple solubility in a few metals, more frequently gives rise to a definite oxide phase. Nitrogen is soluble in a limited number of metals, and although there is evidence of simple solubility in some cases, all metals which dissolve this gas are known to form definite nitrides under suitable conditions. The rare gases, so far as is known, are completely insoluble in all solid metals, but there may be some doubt regarding their solubility in some molten metals. Compound gases can only diffuse into metals after dissociation, and one cannot therefore refer to simple solubility in these cases. As a rule, these gases give rise to at least one compound. The oxides of carbon may give rise to both oxides and carbides in the metal, hydro-carbons to dissolved hydrogen and a carbide phase, water vapour to hydrogen and an oxide phase. These systems are of the greatest practical importance, but so far have received very little attention and in hardly a single instance are the equilibrium conditions known.

The laws of solubility that have been established therefore relate almost entirely to metal-hydrogen systems, and are supported by a limited amount of data for oxygen- and nitrogen-metal systems.

Effect of Temperature

True solution is an endothermic process, and solubility therefore increases as the temperature is raised. As a rule gases are more soluble in liquid than in solid metals, and there is therefore a sudden increase in solubility at the melting-point. Solubility in the liquid metal also

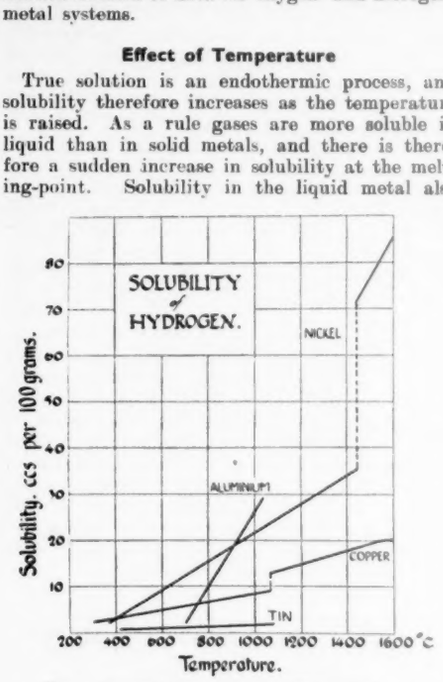

FIG. 2.—SOLUBILITY OF HYDROGEN IN SOME TYPICAL METALS.

increases as the temperature is raised still further. Since, in cases of true solution, the process is quite reversible, there is a sudden evolution of gas when the metal freezes. In Fig. 2 are shown some typical isobars for simple solutions.

Owing to the difficulty of making accurate measurements over an extended range of temperature, the exact form of the isobars is in many cases still uncertain. Solubility should be related to temperature by an equation of the form

$$S = c.e^{-\frac{E_s}{2kT}} \quad . \quad . \quad . \quad . \quad (1)$$

where C is a constant and the exponent E_s represents the heat of solution. If, therefore, log S is plotted against $\frac{I}{T}$ a straight line should be obtained. The data for a number of metal-hydrogen systems in which simple solution takes

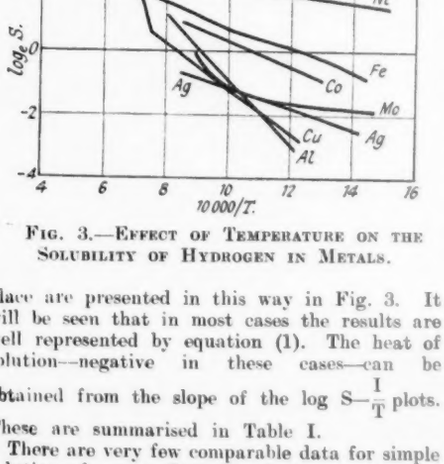

FIG. 3.—EFFECT OF TEMPERATURE ON THE SOLUBILITY OF HYDROGEN IN METALS.

place are presented in this way in Fig. 3. It will be seen that in most cases the results are well represented by equation (1). The heat of solution—negative in these cases—can be obtained from the slope of the log S—$\frac{I}{T}$ plots. These are summarised in Table I.

There are very few comparable data for simple solution of gases other than hydrogen, since in most cases oxygen and nitrogen form definite compounds, but when they do not the effect of temperature may be represented in a similar manner.

There are a number of metal-hydrogen systems in which the solubility does not increase in a regular manner with the temperature. This can in most cases be attributed to the formation of definite hydrides. The evidence for the existence of such compounds is of various kinds. Whilst in simple solution the maximum quantity of gas taken up at atmospheric pressure corresponds to about one atom of hydrogen to 1,000 atoms of metal, in the case of hydride-forming metals the ratio is very nearly stoichiometric, being more nearly one or two atoms of hydrogen to each metal atom. [A palladium wire was saturated with hydrogen and then heated by passing current through it. The hydrogen was rapidly evolved and burst into flame.] The absorption is also accompanied by a very marked dilatation.

X-ray pictures show that as hydrogen is absorbed the crystal lattice of the metal gradually expands, and although the exact position of the hydrogen atoms is not known, they must presumably take up positions between the metal atoms. Further evidence of compound formation is provided by the heats of absorption. In the formation of TiH_2 and ZrH_2 there is an evolution of 36,000 and 40,500 calories/gram mol. respectively. Since in these cases the heats of absorption are positive, solution has a negative temperature coefficient, and solubility decreases with rise in temperature. There is therefore a perfectly clear distinction between these systems and those in which only simple solution occurs.

The isobars may be represented by a log S — $\frac{I}{T}$ plot, as in Fig. 4. Starting at the low-temperature end (the right-hand side in Fig. 4), the

TABLE I.—*Heats of Solution of Hydrogen in Metals.*

Metals.	Heat of solution. Cals. per gm. mol. of H_2.
Aluminium	— 45,500
Silver..	— 11,600
Copper	— 28,600
Nickel	— 5,400
Cobalt	— 17,000
Iron	— 15,600
Molybdenum	— 3,500
Platinum	— 35,400

curve remains horizontal until the hydride begins to decompose, and the solubility then decreases in accordance with equation (1). If the metal be allowed to absorb hydrogen under these conditions until equilibrium is reached, an amount corresponding very closely to the composition of the compound is taken up. At a pressure of 1 atmosphere absorptions are obtained corresponding to ZrH_2, TiH, TaH, ThH_3 and VH. If the temperature be now raised, no further absorption is noted, but a gradual evolution of hydrogen. The temperature at which this begins to take place depends on the dissociation pressure of the hydride.

Hydrogen does not in any case give rise to a compound which separates as a distinct phase visible under the microscope. On the other hand, oxides and nitrides are frequently insoluble in the metal, and when the solid solubility of the gas in the metal is exceeded further absorption results in the formation of a second phase. The best-known example of this is the copper oxygen system. Oxygen is very soluble in liquid copper, but the solubility in solid copper is only about 0.015 per cent. at 1,050 deg. C. When copper which has been melted in air is allowed to freeze, the excess oxygen in solution is precipitated as a copper-cuprous oxide eutectic, and two phases are present in the solid metal.

It is the presence of this cuprous oxide which causes ordinary tough pitch copper to become brittle when heated in a reducing atmosphere. Hydrogen diffuses into the metal and reduces the cuprous oxide, forming water vapour. Now water vapour is not dissociated by hot copper, and it cannot therefore diffuse out of the metal, but sets up an internal pressure, causing cracks which follow the grain boundaries. Iron containing iron oxide does not become brittle when heated in hydrogen, because although the hydrogen diffuses into iron much more readily than it does into copper, water vapour is dissociated by hot iron and no pressure is developed.

The silver-oxygen system is interesting and presents some unusual features. The solubility temperature curve has a minimum at about 400 deg. C., increasing again at both higher and lower temperatures. This means that the heat of

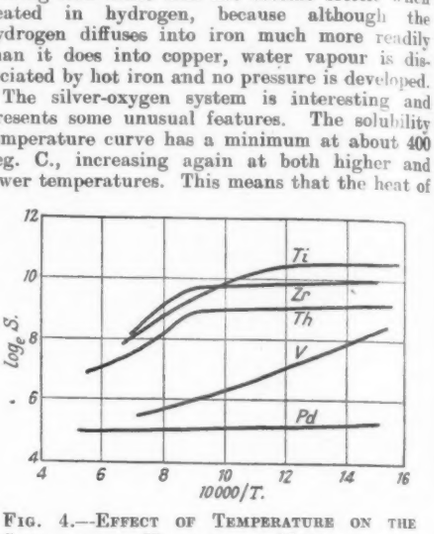

FIG. 4.—EFFECT OF TEMPERATURE ON THE SOLUBILITY OF HYDROGEN IN METALS, ACCOMPANIED BY HYDRIDE FORMATION.

solution is positive below 400 deg. C. and negative at higher temperatures. Since the heat of formation of silver oxide is positive, whilst the heat of dissociation of oxygen is negative, this suggests that the oxygen is mainly present as silver oxide below this temperature, and as dissolved oxygen above 400 deg. C. Silver oxide has a high dissociation pressure above 400 deg. C., and the system therefore illustrates both true solution and compound formation according as the temperature range is above or below this value.

Brittleness can be induced in silver by a process rather similar to the embrittlement of copper. In this case, however, the sequence of events has to be reversed. If silver is first saturated with hydrogen and then heated in oxygen, it is embrittled, the oxygen diffusing in much faster than the hydrogen can diffuse out. If, on the other hand, the metal is first saturated with oxygen, it is not rendered brittle on heating in hydrogen, because oxygen diffuses so rapidly out of silver that it has all escaped before the hydrogen can diffuse in.

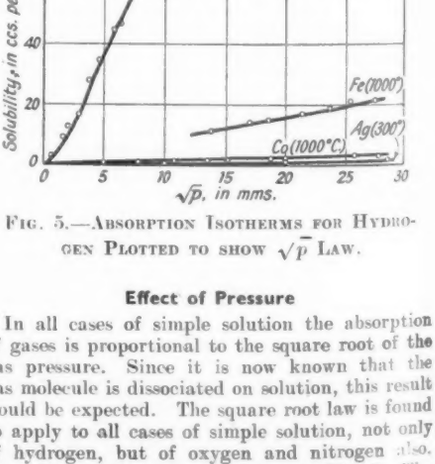

FIG. 5.—ABSORPTION ISOTHERMS FOR HYDROGEN PLOTTED TO SHOW $\sqrt{p}$ LAW.

Effect of Pressure

In all cases of simple solution the absorption of gases is proportional to the square root of the gas pressure. Since it is now known that the gas molecule is dissociated on solution, this result would be expected. The square root law is found to apply to all cases of simple solution, not only of hydrogen, but of oxygen and nitrogen also. Some typical isotherms are given in Fig. 5. The

concentration of gas in solution must be in equilibrium with the surface concentration of adsorbed atoms. It is evident, therefore, that when there is no adsorption there can be no solubility. This is confirmed by experiment, and metals can only dissolve those gases which they can hold by adsorption of the activated type. Thus, the rare gases are not soluble in any metal, and nitrogen, for example, is insoluble in copper or silver.

In cases of compound formation there will be an upper limit to the solubility, corresponding to the composition MH_n when the metal is saturated, and further increase in pressure will not result in increased absorption. This is seen in the isotherms for hydrogen in zirconium, titanium and the rare earth metals. At low pressures absorption is proportional to the square root of the gas pressure, but falls off at higher pressures to an asymptotic value. It is not proposed to give data for the solubility of gases in the various metals. Practically all the common gases and industrially important metals have now been studied, and the data are available elsewhere. It is proposed, instead, to consider the practical effects of the solubility of gases in metals, to give some data on the amount of gases found in commercial metals, and to indicate the effect of these gases on their properties.

Gases in Commercial Metals

When a piece of metal prepared by a commercial process is heated for the first time *in vacuo* a considerable quantity of gas is usually evolved. It is important to realise that such measurements do not necessarily give any information regarding the solubility of the gas or its ability to diffuse in the metal. The gas which is extracted may have been present as blowholes or mechanical inclusions; as an adsorbed layer on the surface; in solution; or in combination. As a rule, it is possible to determine the origin of the gas in any particular case, but a great deal of work has been published in which no attempt has been made to distinguish between these different sources.

The usual method of determining the amount of gas present in a metal is to enclose the sample in a vessel which can be evacuated, and then measure the amount of gas given off at various temperatures. Treatment at any given temperature results in an initial rapid evolution of gas, but this becomes slower and slower until it practically ceases. If the temperature is now raised, a further rapid evolution occurs, but again practically ceases after a short time. At each successively higher temperature more gas can be extracted. It is generally found that the whole of the gas present can only be removed in a reasonable time if the metal is actually melted. Some typical degassing curves are given in Fig. 6. The removal of gases in this way depends on a process of diffusion, the rate of which is governed by the difference in concentration at the centre and at the surface of the metal. As the quantity of gas in the metal becomes less, the relatively small difference in concentration results in very slow diffusion, particularly at moderate temperatures. The very high temperature coefficient, characteristic of all gas-metal diffusion processes, accounts for the sudden increase in the rate of evolution each time the temperature is raised. In the molten metal diffusion is aided by the motion of the liquid metal.

The total quantity of gas that can be extracted from commercial metals by heating *in vacuo* is usually between 1 and 20 c.c./100 grams of metal. With copper and aluminium the gas is largely hydrogen, but with iron and nickel carbon monoxide is the chief constituent. Since, as has been shown, the compound gases can neither dissolve nor diffuse as such in metals, their origin under these conditions is of some interest. The most obvious explanation, which has proved to be the correct one, is that they result from reactions between constituents present in the metal. The evidence for this view is cumulative, but the first definite proof that the CO derived from steel is due to reaction between the dissolved oxide and carbide in the metal was given by Oberhoffer and Piwowarsky, who showed that only a very small quantity of gas was obtained on dissolving steel in mercuric chloride in the cold, but a much larger quantity when the metal was heated *in vacuo*. Mr. Ransley and the lecturer have studied the rate of removal of gases from nickel. It is essential that nickel wire and strip used in the manufacture of valves should be completely gas-free, otherwise the gas is slowly evolved during the operation of the valve with detrimental effects. If commercial nickel wire be subjected to vacuum treatment, about 2.5 ccs. of gas are obtained from 100 grams

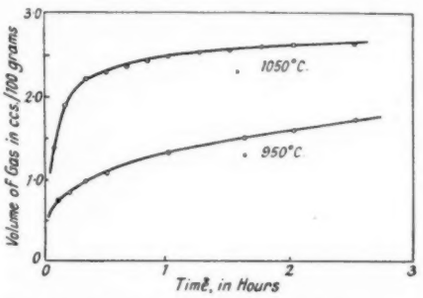

Fig. 6.—Rate of Degassing 1.0 mm. dia. Commercial Nickel Wire.

of metal, and this gas consists of about 80 per cent. CO and 20 per cent. H_2. The hydrogen is removed fairly readily at low temperatures, but the CO requires a longer time and a higher temperature for complete removal. A typical run is shown in Table II. There was a desire to understand the origin of the CO, because it had been found that CO would not diffuse through a nickel diaphragm at any temperature. Since degassing is essentially a diffusion process this seemed to present an anomaly.

The most probable explanation is that carbon and oxygen can coexist in the nickel, for example, as carbide and oxide, and that during vacuum-furnacing these elements diffuse to the surface and there combine and escape as CO. This explanation was confirmed by measuring the rate of degassing at different temperatures and so obtaining the temperature coefficient of the diffusion process.

Table II.—*Evolution of Gas at Different Temperatures from 1 mm. Diam. Nickel Wire Cleaned in Trichlorethylene.*

Time of heating.	Temperature, deg. C.	Gas in c.c. per 100 gms.			Total.
		CO_2.	H_2.	CO.	
20 mins.	750	0.08	0.23	0.36	0.67
20 ,,	850	0.03	0.03	0.33	0.39
20 ,,	950	0.03	0.03	0.54	0.60
20 ,,	1,050	0.05	0.03	0.45	0.53
20 ,,	1,150	0.03	0.11	0.13	0.27
		0.22	0.43	1.81	2.46

The rate of diffusion through nickel of carbon and oxygen was determined separately, as was also the temperature coefficient in each case. It was found that the temperature coefficient for the diffusion of carbon was identical with that for the extraction of CO, whilst that for oxygen was about three times as great. It appears, therefore, that the removal of CO from nickel is controlled by the rate of diffusion of the carbon, and only when this reaches the surface does it combine with oxygen and escape as CO. Actually there is usually an excess of carbon over oxygen in nickel, so that if the surface is re-oxidised after complete degassing, a fresh evolution of CO can be obtained. In practice this means that a gas-free wire may become a source of gas once more if the surface is allowed to become oxidised.

Examples from Steel Making

One type of steel ingot which is produced, for example, for the manufacture of tinplate, is known as " rimming " steel. In this process the manufacturer aims at getting such an evolution of gas during freezing in the mould that instead of forming a pipe, the top of ingot remains flat. Such an ingot has a characteristic structure, and although the manufacture presents no difficulties, the explanation of the phenomena has only recently been understood, due to the work of Prof. Edwards for the Heterogeneity Committee of the Iron and Steel Institute.

A rimming ingot has the following characteristics:—

(*a*) A thin skin of crystals next to the mould due to the sudden chilling of the metal.
(*b*) Beneath this a thicker layer of crystals of much purer iron than the average composition of the steel both with regard to carbon content, and sulphur and phosphorus. This forms a solid wall practically free from blowholes.
(*c*) Next to this an intermediate layer containing a higher concentration of impurities, and a large number of blowholes.
(*d*) A central portion containing impurities and some blowholes. There is no pipe, but a number of blowholes just below the crust.

During the solidification of such an ingot a considerable amount of gas—CO and CO_2—is evolved and bubbles up through the molten metal. Analysis shows that the gas in the blowholes is mainly CO.

At one time it was thought that the gassing was due to liberation of CO originally in solution in the steel, which became supersaturated on cooling. It has been shown quite conclusively that neither CO nor CO_2 are appreciably soluble, as such, in steel; and, in fact, such solubility would be incompatible with all the evidence educed with regard to the equilibria between gases and metals. The explanation of the formation of these blowholes is based on the fact that iron oxide and carbon can coexist in solution in liquid steel, just as it has been shown that carbon and oxygen can coexist in nickel. The position and amount of the blowholes formed during freezing will depend on the total and relative concentrations of carbon and iron oxide in the steel, which give rise to the reaction.

$$FeO + C \rightarrow Fe + CO.$$

Without going into detail, the essential steps are (*a*) the separation of pure iron, which increases the concentration of C and O in the remaining liquid, and possibly causes the precipitation of a cloud of iron-oxide particles, (*b*) reaction between the carbon and iron oxide at the growing surface of the crystals, either due to the rapid loss of heat to the mould, or to the increased concentration, or both. The position and amount of the blowholes will depend upon the initial carbon and oxygen content of the steel.

Reactions of this type are probably more common in metallurgical practice than is always recognised. The process of making tough pitch copper has many features in common. The objective here is similar, namely, to avoid a pipe or contraction when the ingot freezes. It is achieved by a careful control of the oxygen content, but the mere presence or absence of oxygen would not alone achieve this effect, which really depends on the simultaneous presence of both oxygen and hydrogen in solution in the copper.

This reaction at the moment of freezing between gases which in the liquid metal can remain quietly in solution, is the fundamental cause of unsoundness in most cast metals, and in the majority of cases unsoundness in non-ferrous metals is due to reaction between hydrogen in solution and oxygen present either as oxide or in solution in the metal. The origin of

(*Concluded on page* 162.)

World's Steel Castings Production

The subjoined table extracted from "Stahl und Eisen" shows the production of steel castings in the principal steel-producing countries of the world for the years 1929, 1932, 1935, and 1936, and the percentage of these outputs of total steel production in each country for the same years. After the war steel-castings production advanced progressively in all countries up to 1929, the pre-depression peak year, and then commenced to decline, although with some lag, for a decline did not set in in France and Great Britain until 1930. Recovery, also, came in different countries at different times, first appearing in Japan and Luxemburg in 1931, but in Poland and the United States not until 1934 and 1935 respectively. The proportion of steel castings of total steel output in 1936 was only greater than in 1929 in Great Britain, Germany,

TABLE I.—*World Production of Steel Castings in* 1929, 1932, 1935 *and* 1936. (*In* 1,000 *metric tons.*)

Country.	Production in 1,000 met. tons.				Percentage of total steel production.			
	1929.	1932.	1935.	1936.	1929.	1932.	1935.	1936.
Germany, including Saar ..	319.1	182.6	342.8	593.6	1.75	2.52	2.08	3.09
Great Britain ..	170.6	117.6	196.5	245.7	1.74	2.26	2.0	2.1
France	236.8	164.0	152.3	141.0	2.44	2.90	2.4	2.1
Belgium	100.3	38.2	61.3	69.8	2.40	1.40	2.0	2.2
Italy	52.6	42.7	62.4	71.3	2.50	3.10	2.8	3.5
Czecho-Slovakia	48.2	12.0	17.6	30.0	2.3	1.80	1.5	1.93
Poland	30.3	7.9	9.3	10.1	2.2	1.4	0.98	0.89
Sweden	17.4	11.4	19.2	19.0	2.5	2.2	2.1	1.95
Austria	11.6	3.2	4.5	6.0	1.8	1.6	1.2	1.44
Luxemburg ..	9.9	3.2	7.6	9.1	0.34	0.16	0.4	0.46
Rumania	†	†	5.5	6.0*	—	—	2.6	2.5
Europe	996.8	581.8	879.0	1,201.6	1.89	2.20	2.03	2.43
U.S.A.	1,608.4	220.3	154.6	259.1	2.80	1.60	0.45	0.53
Canada	69.5	11.2	32.9	36.0*	5.0	3.30	3.5	3.3
America	1,677.9	231.5	187.5	285.1	2.86	1.02	0.53	0.59
Japan	49.2	46.7	106.1	122.7	2.10	1.16	2.26	2.30
British India ..	3.8	4.1	2.9	3.2	0.65	0.71	0.33	0.34
Asia	53.0	50.8	109.0	125.9	1.82	1.07	1.95	2.23
World total ..	2,727.7	864.1	1,175.5	1,622.6	2.38	1.98	1.39	1.55

* Estimated. † No returns available.

Italy, Luxemburg, and Japan, while in other countries ground has been lost and steel production has expanded to a greater extent than the output of steel castings, particularly in the United States.

At various times after the depression the steel-castings figures for 1929 were exceeded, thus in Japan in 1933, in Great Britain, Germany, and Italy in 1934, and in Sweden in 1935, so that in 1936 European output of steel castings was greater than in 1929. The rapid development of the steel industry in Japan resulted in Asiatic output exceeding the 1929 total already in 1933. On the other hand, in the United States recession continued until 1934 when output was only 6.8 per cent. of the 1929 total and by 1936 it had only recovered to 16.1 per cent. of the 1929 figure. While in 1933 the United States was the principal producer of steel castings in the world, it had dropped to fifth position by 1934 and only recovered to second place by 1936. Since 1934, Germany has been the world's principal producer and in 1936 accounted for more than one-third of the world's total. Great Britain occupied second place in 1934 and 1935, and dropped to third place in 1936, followed in succession by France, Japan, Italy, Belgium, Canada, Czecho-Slovakia, Sweden, Poland, Luxemburg, Austria, Rumania, and British India. Since 1931 more than half of the world's output of steel castings was made in Europe, a share which increased to nearly 75 per cent. in 1935 and 1936.

The Institute of Vitreous Enamellers

FIFTH ANNUAL CONFERENCE

Preliminary details of the fifth Annual Conference of The Institute of Vitreous Enamellers, which is to be held in London next month, are now available. The Hotel Normandie in Knightsbridge has been chosen as the venue.

The annual general meeting will be held on Friday afternoon, October 28, at 4 p.m., followed by the annual banquet at 7 for 7.30 p.m.

In the morning of Saturday, October 29, there will be a visit to the works of the Sterling Manufacturing Company at Cubitt Town. Coaches will leave the hotel at 9.30 a.m. Members will make their own arrangements for luncheon, and in the afternoon a technical session will be held. The meeting will be addressed by Mr. J. G. Pearce, M.Sc. (director of the British Cast Iron Research Association), and Dr. G. T. O. Martin (the recently-appointed Research Officer), on the subject of "Scientific Aids to Vitreous Enamelling." A discussion will take place after tea. The evening will be occupied by a visit to the Palladium.

Sunday, October 30, will be devoted to a whole-day excursion by motor-coach to Hampton Court and Windsor. Luncheon and tea will be taken *en route*, and the party will arrive back in town about 6 p.m.

Gases and Metals

(*Concluded from page* 161.)

both the hydrogen and the oxygen is commonly water vapour in the atmosphere of the furnace, which is dissociated and absorbed by the molten metal. The decrease of solubility on freezing disturbs the equilibrium and the gases react again to form steam—which is trapped as blowholes in the pasty metal. Hydrogen alone diffuses so rapidly through most metals near their melting points that it can seldom develop as bubbles and blowholes. Oxygen alone is usually precipitated as oxides when cooling leads to supersaturation. It is only when both these elements occur together, as they will always do in the absence of special precautions during melting, that unsoundness results. It is felt that if these facts were more widely appreciated some of the difficulties in obtaining sound castings would be overcome.

Heat-Treatable Aluminium-Silicon Alloys

MR. GASTON G. GAUTHIER writes as follows in reply to the various questions raised during the discussion on his Paper* presented on behalf of the French Foundry Technical Association to the Bradford Conference of the Institute of British Foundrymen:—

To Mr. West: Double modification as detailed and used in the research is no more difficult to apply in practice than single modification either by sodium or salts. The first addition of 0.3 per cent. of salt is made in totality during melting, especially whilst the metal is increasing in temperature and such a method introduces no additional difficulty. It can be made by the workman responsible for the supervision of the furnaces. As to the introduction of sodium, this is a well-known and currently used operation.

To Mr. Ashton: The casting temperature cited, that is from 700 to 720 deg. C., is that which has given in practice test-bars showing the best mechanical results. Thus, as was pointed out by Mr. Gürtler, the casting temperature depends on the mould to be filled and is fixed in practice by the pathway the metal has to follow. In order to clarify the situation, the photograph, Fig. A, shows the actual test-bar referred to. A metre rule is included so as to indicate the dimensions.

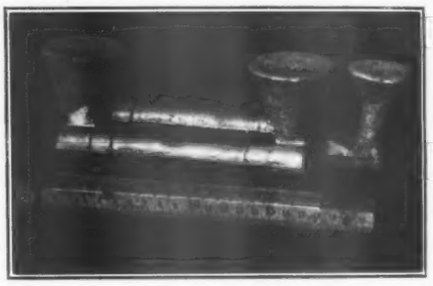

FIG. A.—TEST-BAR USED.

To Dr. Hunt: The question raised by Dr. Hunt arose from a typing error, for which the author apologises. The phrase should have read: "It is true that the mechanical properties are surpassed by those of certain alloys containing copper and titanium, etc."

Catalogues Received

Air Conditioning. Two pamphlets received from Davidson & Company, Limited, Sirocco Engineering Works, Belfast, deal respectively with an air conditioning installation for sugar refining and packing and the heating, ventilating and air-washing equipment for Sheffield Corporation. They well maintain the high standard of publicity one always associates with this firm's productions.

Electric Motors. In their loose-leaf catalogue, Higgs Motors, Limited, of Witton, Birmingham, have changed six sections. This involves replacing the old ones by those just received. The new sections relate to fractional horsepower motors, slip-ring and squirrel-caged totally-enclosed induction motors; protected, screen protected, and totally-enclosed plain bearing machines; direct current dynamos and gear units.

* FOUNDRY TRADE JOURNAL, June 16, pp. 435 *et seq.*; discussion, July 14, pp. 26 and 27.

The Grinding of Raw Materials

SOME FUNDAMENTAL CONSIDERATIONS

A real service to those industries which include the pulverisation of materials as part of their processing has been performed by "Chemical and Metallugical Engineering." In a recent issue it devoted a complete supplement of 18 pages to the subject. In what follows we have abstracted portions which are particularly appropriate to the vitreous enamelling industry.

MR. WALTER L. MAXSON, writing under the heading, "A View of Grinding Fundamentals," points out that grinding refers to relatively fine size-reduction, but may be described as coarse, intermediate, or fine, with the limits roughly set at 6 to 35 mesh for coarse, 35 mesh to 70 per cent. minus 200 mesh for intermediate, and 70 per cent. minus 200 mesh down to 10 microns for fine grinding. Such designations, however, are not fully descriptive inasmuch as they portray the unlocking only in terms of mesh size. A more exact method of indicating the disintegration required is to define it as to: (*a*) mesh size; (*b*) release; (*c*) specific surface; and (*d*) grouping. These terms are not arbitrary but may serve to draw attention more forcibly to the exact nature of any grinding problem with which the operator may be faced.

Types of Grinding Defined

"Mesh size" grinding is practised in many industries where it is necessary only to control the ultimate products in terms of some limiting mesh.

"Grinding for release," or "unlocking grinding," has reference primarily to the type of operation required for many chemical and metallurgical processes where it is necessary only to expose surfaces for attack by gases or solvents as, for example, in exposing particles of a valuable material that have been locked in a gangue.

"Specific surface" grinding has reference to grinding for the production of surface in contradistinction to grinding through a limiting mesh. Although it has been practised in various industries for many years, the methods of control are new. An empirical measurement for the surface in the product is now used. In general, the specific surface is designated as the square centimetres per gram of ground material, and one of the newer methods of measurement is to use a turbidimeter, which offers a reasonably accurate and rapid method of making empirical comparisons.

In some industries a normal product would have a specific surface from 1,650 to 1,700, whereas an extremely fine product would have a specific surface ranging from 2,600 to 2,800. The latter in terms of mesh size would represent a product which might possibly run 94 per cent. passing 325 mesh, or approximately 96 per cent. passing 40 microns, but it is possible to grind to these limiting mesh sizes without developing the required specific surface. Therefore, it is proper in operations of this kind to control the grinding units by surface measurement rather than by mesh measurement.

"Grouping or size modulus" grinding has reference to those operations where it is desirable to control the product within certain ranges of mesh size. While this is not at all an unusual requirement it has been brought to the fore markedly in recent years by the work of engineers in the aggregate industries where it is desired to produce mixtures having minimum void space. The practice has resulted in some rather remarkable savings in raw materials required.

A careful study of disintegration operations reveals that they take place as a result of (*a*) impact; (*b*) differential movement of adjacent surfaces; or (*c*) combinations of both. Further analysis of differential movement shows that here again the action may be produced by surfaces whose movement is more or less controlled, or by surfaces whose movement is heterogeneous. There are, obviously, combinations of both. For example, the average cylindrical mill may, and usually does, involve both impact and differential movement, and while the action may be controlled within reasonable limits, it is an example of an operation which may be properly designated as heterogeneous. Those types of grinding wherein impact is of relatively little importance, and where the surfaces are controlled, are represented by mills having fixed or rotary die rings with rollers or balls acting as breakers. There are also the simple impact devices such as the swing hammer pulveriser, in which the breaking is effected very largely by impact.

Experience has shown that, when breaking crystalline products, with or without matrix present, there are distinct grain sizes which may be released at various stages in the operation, which may or may not offer great resistance to breaking. In some cases it has been found relatively easy to break the matrix and quite difficult to break the grains. In other cases the matrix is resistant and the grains relatively easy to grind once the matrix has been disintegrated.

The abrasiveness or coefficient of friction of the feed is also an important element in proper selection and operation of grinding units, inasmuch as certain types of equipment cannot be used for extremely abrasive materials. Those materials which are slippery, such as coke or some of the coals, offer resistance because of the difficulty in nipping the slippery particles between the grinding surfaces.

Velocity of Impact

Investigations have been made on this point, and it may be said that with materials which are extremely hard to break, particularly in the coarser mesh range, higher velocities are warranted. However, with softer materials the use of high velocities of impact may result in low power efficiency. There is also a relationship between the velocity of impact and the choice of materials used in the disintegration unit, for with higher velocities wear may dictate the use of special alloys. This, in turn, may lead to an uneconomical combination as regards ultimate cost of grinding.

Character of Surfaces

This heading covers not only physical character and composition of the grinding surfaces, but also their shape, and progressive changes in shape due to wear. In the case of cylindrical mills with heterogeneous action of the grinding media, and with differential movement as the predominating grinding action, it is necessary that the particles be nipped between the grinding media. A recognition of this fact has led to various experiments making use of several different shapes such as cubes, tetrahedrons, cylinders, spheres, concave-convex bodies, spheres connected by cylinders, and other miscellaneous shapes. Comparisons involving both mesh-tons and surface produced within the range of normal grinding show little advantage in special shapes, although in the case of extremely fine grinding some marked increases have been shown.

In any case, it is necessary that the grinding media offer the necessary surface without at the same time impeding the flow of the material to be broken. It is often desirable to discharge the entire content of a grinding unit regularly and eliminate the slivers, flats, and distorted shapes resulting from wear. Upon replacing the charge a marked increase in capacity is apparent.

It is also necessary that the grinding media shall be of such shape that they are not sluggish in their movement, as the production of new surface is effected only by relative movement of the grinding media, and a sluggish charge is rarely an efficient charge.

Where controlled surface units are used for disintegration, the progressive change in shape may become quite pronounced if the material is at all abrasive, and may dictate the selection of materials used, and the application of such units for disintegration problems.

The relative weight of the media used for disintegration is also of importance, particularly in those cases where materials of high specific gravity are to be broken. This factor is not always recognised, but must be seriously considered. Unfortunately, it is not economical to use the special weighted grinding media, but the use of heavier than normal grinding bodies has been adopted in a limited number of cases.

Size of Feed

The size of the material fed to the disintegrating unit is usually determined by economic factors. For example, it is usually cheaper to break the material down to ½ in. or 4 mesh in gyratories or rolls than to feed material larger than this size to cylindrical mills or similar types of grinders. The size of the feed is related to its constitution, and in the case of soft materials there may be very little gain in the grinding stage by charging fine feed, whereas in other cases the preliminary breaking unit may provide a considerable amount of finished product, thus relieving the grinding stage of a part of its duty. In general, it may be said that grinding is more expensive than crushing and there is, therefore, incentive to reduce the size of feed within economical limits.

The size of the feed is quite important as regards the selection of the grinding media. The latter must have sufficient mass and develop sufficient kinetic energy to break the coarsest material effectively. However, as the mass of the individual units is increased the area available for grinding and the number of points of contact available per cubic foot of volume are decreased, and it is necessary, therefore, that an empirical balance be established between the size of feed and the size of grinding media.

It has been repeatedly demonstrated that as the size of the material is reduced, progressively smaller grinding media can be used economically. This is particularly emphasised in those cases

where finished material is progressively removed from the circuit. The practice has probably met its widest application in the grinding of cement clinker.

Mill Speed

In cylindrical grinding mills, speed is important in that to a large extent it determines the number of cycles made by the grinding media in a unit of time. It also serves to change the contour of the grinding mass. In those cases where it is desired to have impact predominate, it is necessary that a higher speed be used.

There has been a certain amount of loose thinking in connection with mill speeds, particularly with reference to the term "critical speed." The critical speed is an evaluation of gravity versus centrifugal force but, unfortunately, the real critical speed developed in a cylindrical grinding unit, while related to the theoretical, is affected by other factors such as the sluggishness of the charge, weight of charge, shape of liners, and relative size of feed and grinding media. In wet grinding the amount of moisture will also affect the charge contour. Essentially, the shape of the charge contour with specific reference to the location of the apex is of major importance in determining the type of grinding and the work to be done in a given unit. The same apices may be secured in the same mill by operating with a low ball charge at a high speed, or by operating with a higher charge at a lower speed. However, experimental work in the cement industry has led to the conclusion that ball charges should not be too low except for special cases and types of operation. Furthermore, it is evident that the mill speed must be correlated with the weight of charge to secure optimum grinding.

There have been numerous attempts to alter the action of the grinding media by modifications in the shape of the grinding unit. Careful tests show that the amount of new surface produced per revolution of the mill is practically constant for any given unit. Little or no advantage in net production can be gained by attempting to alter the normal movement of grinding media by changing the shape of the unit.

Type of Liner

Liners are used in cylindrical mills for two purposes: to protect the unit against wear, and to provide means for controlling the action of the ball charge. The proper contour of liner is of importance, and should be carefully considered from the standpoint of mill speed and weight of charge used. For example, if the liner provides a maximum lifting effect it is necessary that the speed be reduced, for otherwise the grinding media may be carried so high as to reduce their effectiveness in grinding. On the other hand, with smooth liners which offer a minimum of lifting effect, the mill speed must *per se* be increased for the same ball action. With all types of friction liners there is a steady change in contour and decreased lifting effect during the liner life. The mill speed should be selected for half-life contour, although variable speed operation would be preferable.

Size of Grinding Media

The size of the media used for grinding, whether rods, pebbles, balls or other shapes, is a major consideration. If impact is desired the kinetic energy of the individual unit becomes quite important, sometimes even more so in wet grinding than in dry grinding since there may be a pulp pool in the unit which tends to rob the falling media of a portion of their kinetic energy before they do useful work. In any case, it is desirable that the grinding media be large enough compared to the maximum size of feed so that they may effectively nip the particles.

It is to be recognised that there is progressive wear on any grinding medium, and it is, therefore, desirable that this be taken into account in selecting the initial charge and in replacements. In dry grinding, where the rate of wear is usually considerably lower than in wet grinding, the progressive change is less marked, as it is in the heterogeneous type of mill, as compared with the controlled surface type. It is sometimes necessary to remove the ineffective grinding media periodically if reasonable efficiency is to be secured. This is particularly true of media which change form materially as they become worn.

Flow Rate

The determination of proper flow rate in any type of grinding device is subject to experimental confirmation by actual operation. It is improper to assume that any specific flow rate will give best results until it has been proven in practice. The term "flow rate" refers primarily to the average rate of travel of material through the unit from feed to discharge. It is recognised that increases in flow rate where the units are operated in closed circuit make it possible to modify somewhat the distribution of surface and mesh size produced by a given unit.

The production of fine sizes requires a great expenditure of energy, and a grinding unit obviously should be operated to reduce to a minimum the production of sizes finer than required. There are limitations to the flow rate, but these have been demonstrated to be different for each problem. Laboratory tests serve to give preliminary information and in some cases rather striking agreement with the flow rates determined by laboratory testing has been obtained in operating units. For any given problem there is an optimum flow rate beyond which there appears to be no great gain in ultimate capacity of finished material. This is undoubtedly greater with softer materials than it is with those that are more resistant, and it is an interesting fact that the optimum flow rate may radically change when finishing the same material at different meshes or at different amounts of new surface.

In the case of dry grinding the problem is not quite so simple because the means available for the control of finished product do not make it possible to delineate the sizing as closely as when wet separations are used. The problem is further complicated in dry grinding since it is not possible to secure flow rates of the same magnitude as those obtained in wet grinding.

The flow rate may be controlled by the use of classifiers, screens and air separators. In some cases the rate can be somewhat modified by air-sweeping the unit. This is not always effective, as there may be a tendency for the air currents to sweep only the surface, which may result in a steady accumulation of extremely resistant material to be ground.

Using screens and wet classifiers often permits greater flow rates than can be obtained with the other devices mentioned. However, the use of screens is limited by the blinding effect of particular sizes and shapes of material in the screen fabric. Therefore, it is essential when producing fine sizes in dry grinding to use air separators, or else to operate in open circuit, or on a batch basis. The flow rate is affected by mill speed, size of grinding media, and by the size distribution of the material fed to the unit. In some cases it is necessary to add fine sizes to the feed in dry grinding to produce enough mobility in the charge to secure sufficient flow rate.

General Considerations

Sometimes corrosion of machine parts, or contamination of product dictates the choice of mill and grinding media materials. Where contamination is serious it may even be necessary to grind the material with larger pieces of the same material. This, in general, is not economical, but sometimes necessary. Danish pebbles and porcelain balls have been used successfully, as well as special alloys. Rubber-covered rods and balls have been employed with and without lead or iron centres to increase their weight. Special liners made of porcelain, silex, rubber, and alloy steel are sometimes utilised.

In general, when wet grinding can be used it is preferable because of the elimination of dust, and because it is in most cases more efficient in the use of power. In dry grinding consideration must be given to the coating of grinding media and to the cushioning effect of the material to be ground. Coating of balls or liners may be serious and in some cases resists all efforts to prevent its formation. In general, cushioning can be controlled by providing means in the grinding unit for the rapid removal of contents. It is recognised particularly in cylindrical grinding vessels that discharge of the contents near the periphery or by some special means may be particularly advantageous. This does not apply to all problems, but it is obvious that the unit should be designed to prevent the accumulation of finished material.

More than one type of mill will usually be able to give the desired grouping of particle sizes, or the mesh size, unlocking or specific surface needed so that choice will usually depend on economic and operating factors. In the absence of identical operating information from similar plants, it is necessary to test the material carefully under controlled conditions. However, it must be emphasised that there are wide differences in the constitution of materials which are superficially similar, a fact which is best illustrated by reference to tabulations of comparative grinding resistances of different materials. Even a casual scrutiny of such data will make it clear why it is necessary to have great variations in the size of units for grinding the same tonnages, and why careful tests are needed if optimum results are to be attained in a grinding installation.

Efficiency of grinding units is always an economic question, but the factor to be emphasised will vary with the particular conditions. In some cases the requirements of the product may warrant an operation that is far from economical, while in others, cost efficiency as reflected in low power consumption, long life, and low wear may be of paramount importance. Still again, maximum capacity may be the criterion. These and the factors considered in preceding sections must be given their due weight if a satisfactory installation is to be achieved.

GRINDABILITY

Another contribution to the symposium is an editorial report on "Grindability *versus* Mill Capacity." In this, it is stated that grindability

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3 Report of Committee D-5 on Coal and Coke, A.S.T.M., June, 1933, D-408-35T and D-409-35T.

4 "Pulveriser Performance as Affected by Grindability and Other Factors," by M. Frisch and A. C. Fostor, A.S.T.M., June, 1937.

5 "Effect of Grindability on Particle Size Distribution," by R. M. Hardgrove, Trans. A.I.Ch.E., April 25, 1938.

6 "A Method of Rating the Grindability or Pulverisability of Coal," by C. E. Baltzer and H. P. Hudson, Report 737–1, Bureau of Mines, Canada, 1933.

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10 "Check Determinations of Grindability of Coal by Various Methods," by W. A. Selvig, U.S. Bureau of Mines, Feb., 1936.

11 "Investigation of Procedure for Determination of Coal Grindability by the Ball Mill Method," by C. G. Black, A.I.M.E., Feb., 1936.

12 "Grindability of Coal from the Producer's Viewpoint," by R. M. Hardgrove, Appalachian Coals, Inc., Jan., 1937.

13 "A Method for Estimating the Efficiency of Pulverisers," by R. Wilson, A.I.M.E., Feb., 1937.

is that characteristic of a substance which determines the capacity of a given pulveriser for reducing the material to a standard fineness. Numerically it is directly proportional to the specific gravity and inversely proportional to the crushing resistance. Grindability is useful principally in estimating pulveriser capacities and power requirements.

Determinations of grindability are made by a number of methods, two of which have been adopted as tentative standards for coal by the A.S.T.M.[3] These are the Bureau of Mines[1] method and the Hardgrove[2] method. The former method makes use of a ball mill equipped with ribs to prevent slippage. Grinding is done in eight or nine stages with fines removed after each stage, although the charge is not "sweetened" by the addition of more raw material. Later revisions in the A.S.T.M. tentative standards allow use of a shorter proximate method consisting of four stages for certain cases.

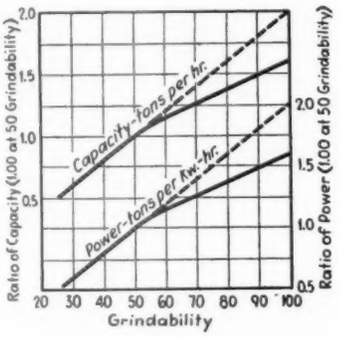


Fig. 1.—Average Performance Curves for Five Sizes of Ball and Race Pulverisers.

The Hardgrove method makes use of a special ball and race type mill with a standard weight (64 lbs.) on the balls. The machine is equipped with an automatic revolution counter which stops it after exactly 60 revolutions. Therefore, the grindability of a material is easily determined by weighing out a 50-gram sample, placing it in the machine for 60 revolutions and screening the product. The Hardgrove grindability index $= 13 + 6.93\ W$, where W is the weight in grams through a 200-mesh sieve. This straight-line relation, determined by 550 tests, has greatly simplified the operation by eliminating many of the testing sieves required.

Numerous materials have been tested by this method, results for some 200 of which have been tabulated in a recent Paper by Hardgrove.[3] The tabulation indicated that grindability may vary all the way from 2 to 204 and that the grindability of a single substance may vary considerably depending on the place of origin.

Some typical grindabilities of various ores and chemical process raw materials are shown in Table I.

Fig. 1 is a summary of a number of curves reduced to a common capacity basis showing the relation of grindability to capacity and to power requirement of a coal pulveriser. These curves are applicable to any size of pulveriser because the characteristics are similar throughout. It is obvious that capacity is directly proportional to grindability in the lower range (30 to 55), but at higher grindabilities capacity falls below the proportional line. This is due to the cushioning effect of material finer than 200 mesh which has not been removed from the grinding area. It has been found, however, that if less than 25 per cent. of the material around the balls is finer than 200 mesh, no appreciable cushioning occurs. Therefore, in efficient closed-circuit systems, which have thorough fines-removal, capacity may be maintained proportional to grindability in the higher grindability range.

Table I.—*Typical Grindability of Various Materials.*

Alum	67
Barytes	120
Bauxite	56
Borax	73-143
Cellulose acetate	7
Chrome ore	45-55-56-70
Clay	74-135
Dolomite	112
Feldspar	43
Fluorspar	92
Graphite	51
Ilmenite	43
Kieselguhr	132
Lime	105-135
Mica	7
Oyster shells	59-63
Phosphate, tri-calcium	134
Quicklime	138-180
Resin, unground synthetic	14
Rosin	175
Rutile (TiO_2)	26
Salt	54
Sand, silica	24-50-55
Shale	37-204
Slag	32
Sulphur, raw	90-104-134
Talc	67-70-74-84-121-125-130
Zinc blende ore	136
Zinc oxide	96-103

Power required to drive a pulveriser at full load is, as demonstrated by the lower curve in Fig. 1, practically constant for all grindabilities, delivering a product of the same fineness. Note that power is expressed in tons per kw.-hr. instead of the reverse, in order to show the similarity to the capacity curve.

In connection with Fig. 1, it should be emphasised that the data plotted are representative only of a specific type of mill. Other types show a somewhat different relation between capacity and grindability as pointed out by Frisch.[4]

Grindability is not the only factor affecting mill capacity. Fineness also plays a part, as shown in Fig. 2. Thus, to find the capacity of a pulveriser for a given material (assuming the pulveriser has already been calibrated by grinding a material of known characteristics), only a simple calculation is required. Using the grindability of the material, determination of the grindability component of the capacity factor (read on the ordinate) is made from Curve B in Fig. 2; then using the fineness desired, the fineness component of capacity factor (also read from the ordinate) is determined from Curve A. The product of these two is the capacity factor and by applying it to the calibrated capacity, an estimated output may be determined. Power requirement, based on an assumed 6 kw.-hr. per ton for the pulveriser alone, may be estimated as 6 divided by the capacity factor.

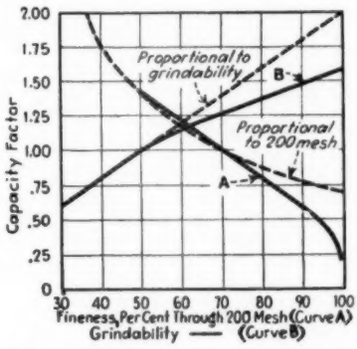


Fig. 2.—Effect of Grindability and Fineness on the Pulveriser Capacity Factor.

Practically, grindability has little effect on the total power cost. Comparing the cost of pulverising coal of 100 grindability and coal of 45 grindability (an extreme case) showed that maintenance, power, and fixed charges amounted to a little over 3 cents per ton more for the latter coal (figuring power at 0.2 cent per kw.-hr.). So the general conclusion is that grindability tests find their chief use in deciding on proper size of equipment to install in a given plant and determining whether or not an existing installation has sufficient pulverising capacity to carry the load with a given material.

Gas Opacification of Vitreous Enamels

The opacification of vitreous enamels is usually effected by means of the addition of the oxides or other compounds of certain metals, such as tin, antimony, zirconium, cerium, arsenic, etc., these additions either being incorporated in the raw materials forming the frit or being added to the melted frit when it is ground. The opacity is caused by very minute particles of these (what might be called "solid") opacifiers being very highly dispersed throughout, and suspended in, the enamel layer, causing the light which falls upon the surface of the enamel to be reflected, refracted or diffracted, instead of its being able to pass through as would be the case with transparent or un-opacified enamels.

The degree of opacity created by the addition of "solid" opacifiers is enhanced by the presence of volatile gases which form very minute bubbles in the melted enamel, this being due principally to the action of fluorides contained in the frit. Until recently, however, it was never considered that the presence of such gaseous bubbles, without the addition of a "solid" opacifier, would be sufficient to attain the requisite degree of opacity but, after many years of intensive research work by Dr. Ignaz Kreidl, of Vienna, it has now definitely been proved that not only it is possible to attain this result, but that a higher degree of opacity can be obtained by gas opacification alone than by the use of even the most intense "solid" opacifier when this is also used alone.

Mechanism of Gas Opacification

Gas opacification is achieved by the addition of gas-producing media to the enamel in the grind. The media volatilise during the firing of the enamel, and the bubbles formed by the volatile gases impart the requisite degree of opacity. Control of the manufacture ensures that these bubbles are all of a very minute size and, owing to the nature of the enamel, it is impossible for these bubbles to escape and give an enamel of inferior opacity even on over-firing. To attain the best results (as in the case of "solid" opacifiers) it is necessary that the composition of the frit should be favourable to the method and material employed, as for instance in the case of the "solid" opacifier, tin oxide. When 6 per cent. is added to an enamel having a favourable composition, a good opacity will result but, if the same proportion be added to an enamel of unfavourable composition, it is possible for the tin oxide to enter into solution without yielding any opacity whatsoever.

The study of the corresponding frits has, therefore, been an important feature of the research work that has been undertaken, and a range of frits has been evolved to suit all temperatures and conditions which, whilst lending themselves to successful gas opacification, also possess all the other features necessary to meet the exacting requirements of the enamelling industry.

Although this process is new to the United Kingdom, it is being used extensively on the Continent, especially in Germany, Austria, Poland, Italy and Czechoslovakia. Dr. Stuckert, the eminent German technical expert, summarises as follows the results of very exhaustive experiments carried out in works and laboratories:—"The application properties of the enamel manufactured with G.T.M. (the gas opacifier) lie within the technical application interval. In this respect there is no restriction on its use. Moreover, the gloss and acid-resistance properties conform to the standard required. The present examinations have shown also that in respect of the other characteristics demanded, *viz.*, opaqueness, sensitiveness to firing, heat stability and bending strength, the gas-opacified enamels fulfil the technical requirements. The gas opacifiers can therefore be considered as being in the first class and fully equal to tin oxide."

Tin Oxide Opacifier

Tin oxide is one of the oldest and most reliable "solid" opacifiers, the usual amount added at the mill being from 5 to 7 per cent. It is possible with the gas opacifier to obtain a better result, using 6 per cent., than can be obtained by the addition of even 8 to 9 per cent. of tin oxide. The fact that this higher opacity is given by the smaller proportion of opacifier is obviously an advantage from an economic standpoint.

No additional plant is needed when the gas opacifier is used, and the method of application differs in no way from the standard practices. It is claimed that existing enamels can be matched in every respect and any research which in special cases might be necessary can easily be undertaken by the makers and it is possible to cater for any requirement. In cases where enamelling firms prefer to manufacture their own frits, the formulæ of the frits deemed to be the most suitable for their particular purpose are furnished, and arrangements are made for the supply of the gas opacifier.

By the use of this opacifier conjointly with the suitably determined frits, the best grade of enamels are capable of being produced, having a high degree of brightness, whiteness, opacity, acid and alkali resistance, thermal-shock resistance and firing stability. These enamels are also non-poisonous, easily workable, and economical in use. Owing to the present-day demand for a non-poisonous enamel, gas opacification, because of the harmless character of the materials used, is peculiarly adapted to fill this need. None of the highly-poisonous elements such as antimony, lead, or arsenic is used, and the enamels will therefore conform to any present or future requirement in this respect.

A further claim for gas-opacified enamels is that they are more resistant to over-firing than enamels of the "solid" opacified type, and that they are also capable of withstanding more repeated firings (even as many as six to eight) without any consequent loss of opacity. The price of the gas opacifier should be lower than that of the majority of opacifiers on the market as it is not subject to fluctuation, whilst the cost of the materials comprising the special frits to be used with this opacifier rules lower than that of the usual standard types.

The principle of gas opacification can be applied to all wet-process enamels for all types of metal, and patent specifications have now been registered which will enable the process to be adapted for "dry-process" work.

A Modern Handling Plant for Enamel Constituents

It is known that there is a possibility of the incidence of pulmonary diseases arising amongst operators charged with the handling of the materials used in the manufacture of frit for vitreous enamelling. Especially intelligent methods have been created by the management of the Gothic Works of R. & A. Main, Limited, at Edmonton, London, N., not only for the minimisation of the dust hazard, but for combining with it reduced handling costs associated with enhanced compositional control.

The bulk of the raw material arrives at the works by lorry, and an unloading station has been erected at body-base level so that the mobile "heavy" or general labour gang can easily man-handle the sacks by means of a barrow. There is a small inclined ramp to negotiate, which brings the staging some eight or ten feet above shop level, and permits of entry to a corridor situated at the back of the service bins. Here each of the evenly-spaced bins is provided with a double closure. The inner one is of a permanent character and consists of a rubber curtain, arranged in the fashion familiar to most enamellers in connection with rotary shot-blast tables. The outer closure is merely a wooden slat fitting into a pair of vertically disposed slots. Each slat bears in very bold letters, "Not to be removed without the express permission of the management," or words to that effect. When a consignment of quartz, felspar or the like is received, an executive removes the slat and opens a valve which causes suction to be created along piping terminating in an inlet situated at the very position where a man's face would be when withdrawing the bag from the bin-opening.

The Weighing-Out System

For the weighing-out of the raw materials, access to the bins is had by a simple slat closure situated at the base, and the advantages of the ordinary shovelling method have been retained, whilst eliminating its drawbacks. About eight feet above ground level a double trackway has been erected, one line being contiguous to the wall of the bins, and the other spaced about 2 ft. 6 in. away from it. Depending from it is a cradle mounted on ball bearings. This cradle fulfils the following functions: it is a weighing machine; it carries a portable removal bin; it automatically connects the upper part of the bin and the shovelling area with the dust exhaust system. The weighing machine is of the Avery dial type, but the actual scale is covered and padlocked and there are inserted at the correct places a number of lettered pointers. This system has been adopted not so much with the idea of keeping mixtures secret, as to make for ease of operation, as the pointers are definitely indicative and refer to the bins carrying similar inscriptions. It rightly throws the onus of the mixtures on to the management and enables changes to be made without discussion with the operator.

The portable bins have had to have a good deal of ingenuity incorporated in their design, which calls for (1) handling by lift truck for insertion into the weighing cradle; (2) a shape which will admit of their complete emptying into the mixing mill or later into the smelter without undue knocking; and (3) sufficient robustness to give a reasonably long working life. In spite of all the precautions taken, a distinct variation in weight was noted, and each bin has inserted beneath its upper flange a length of angle iron cut to such a length that a definite constant weight has been achieved.

Automatic Valve Operation

The actuation of the valves situated in branches of the main duct running along the top of the bins has been cleverly effected by installing along the top of the cradle a piece of flat iron, bent so as to form a bridge. The bridge terminates at either end with a ramp. As the cradle is pushed along the length of the bins, a lever terminating in a wheel is raised as the wheel runs up the ramp, and this action opens the valve of the branch from the main suction line. This connects the exhaust system with an inlet situated directly above the portable bin being loaded. At the other end of the bridge a second wheeled lever is resting just on the position before the incidence of the downward ramp and this one has opened a second valve, making contact with the position where the shovel leaves the bin. Thus dust is extracted at the two cardinal points.

As the cradle is moved along to, say, the next bin, then the first wheeled lever runs along the crown of the bridge to come to a halt at the position previously occupied by the second. This latter, in the meanwhile, has run down the ramp and so has closed its valve, whilst a third valve has been opened by the operation of yet another wheeled lever. The exhaust aperture for the removal of dust arising from the actual transfer of a shovelful of raw material is about 2 ft. long by 6 in. wide.

As a precaution against parasitic drafts, there is suspended from an extension to the cradle a full-length curtain at a distance from it of some 2 ft. 6 in. or 3 ft., which allows an adequate working space for the operator.

All the portable bins, when filled, are covered with sheet metal lids, with the dual object of protection against loss by drafts or contamination by extraneous dirt. It should be stated, however, that to the casual observer both seem rather remote possibilities in such a clean and well-ventilated shop. Yet the management has to envisage such occasions as doors being opened to admit of fresh machinery.

As previously mentioned, the portable bins are "stooled" for transport by lift trucks, and after filling they are transferred to the mixing mills. These are of the type where a horizontally-disposed cylinder rotates clockwise and a series of internal blades counterclockwise. The portable bins are lifted by a hand-operated crane and teemed by the aid of a specially designed funnel into the mills. At this point, and also when emptying the mills, a proper dust-exhaust system has been arranged.

Because of the heat, such a system is difficult if not impossible to install for the feeding of the smelters with the raw materials. Thus, along the roof immediately above the smelters, is a series of holes connected to a simple exhaust system leading straight into the open air.

The exhaust from the other operations carries the dust into a bag collecting system; being of such a heterogenous character, this dust is unsuitable for entering into the manufacture of frit for vitreous enamelling.

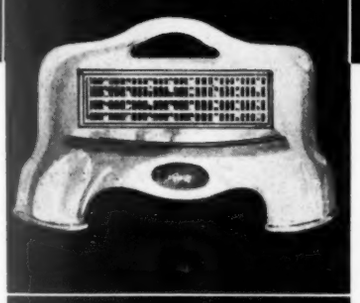
The plant which we have described has been designed and installed by the staff of R. & A. Main, Limited, with the co-operation of the Factory Inspection Department of the Home Office.

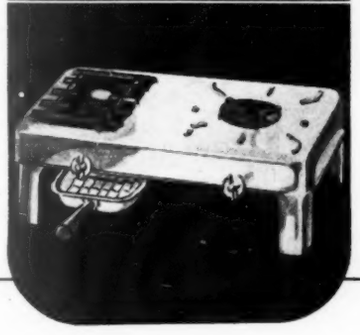
In conclusion, the writer wishes to express his sincere thanks to the company and staff for the facilities accorded to him in the preparation of this article.

TWO GIFTS of £10,000 each have been made by Sir Robert Hadfield to the new Sir Robert Hadfield Metallurgical Laboratories, which will be opened at the Applied Science Department of Sheffield University on September 14 by Sir William Bragg, O.M., President of the Royal Society.

COLOUR *in the home*

BLYTHE COLOUR *of course!*





Colour is a "best-seller."

The modern trend in all domestic utilities is for more and more colour—colour to match decorative schemes, colour to give sales appeal, colour for itself alone, in every kind of household appliance from cookers to sinks.

The manufacturer of vitreous enamelled ware who wishes to be on top of the trend will make his wares attractive by full use of the comprehensive range of Blythe coloured enamels and colouring oxides for cast-iron.

Blythe colours, enamels & materials

Blythe Colour Works, Ltd., Cresswell, Stoke-on-Trent

RB 13

The Week's News in Brief

Trade Talk

F. M. CHARLES & COMPANY, LIMITED, of 83, Pall Mall, London, S.W.1, agents for Utard foundry equipment, have changed their telephone number to Whitehall 3955.

THE L.N.E.R. have decided to construct a special trolley wagon, capable of carrying a dead load of 120 tons, which will be the largest and heaviest single freight carrying unit in Great Britain.

COLEMAN FOUNDRY EQUIPMENT COMPANY, LIMITED, whose present works are at Letchworth, are erecting larger premises at Stotfold, Beds. They expect to be installed in the new works within the next month.

SIR JOHN JARVIS, M.P., speaking at Jarrow recently, announced that they had decided to extend the tube works and he was considering new proposals which, he hoped, would result in further employment for Jarrow men in the near future.

READERS WHO WERE INTERESTED in our description last week of the "Rotavac" oil burner and desire additional information should write to the head office of Nu-Way Heating Plants, Limited, 89, Macdonald Street, Birmingham, and not to the address given in the article, which was incorrect.

FEWER NEW COMPANIES were registered in England and Scotland in 1937 than in 1936, the number falling from 14,381 to 13,344—a drop of 1,037. According to the Board of Trade annual report on companies, these new undertakings had a total nominal capital of £120,302,501, a reduction of £44,119,537 compared with 1936.

THE MANCHESTER ASSOCIATION OF ENGINEERS have been invited to inspect the Partington Gas Works of the Manchester Corporation on Saturday, September 17. The visit will commence at 3 p.m., and on the conclusion of the inspection the members and ladies are invited to have tea, after which the bowling green and tennis courts, etc., will be placed at the disposal of the party.

HEAD, WRIGHTSON & COMPANY, LIMITED, of Thornaby-on-Tees, have successfully negotiated a contract from the Malay States for the supply of manganese steel spares for dredgers in the tin-producing districts. These castings have to withstand the most exacting service conditions, and are to be produced in a special grade of steel. This order is the first of its kind received in the Tees-side area.

A COMMITTEE OF INQUIRY which has been investigating the prospects of the erection of a new blast-furnace plant at Norrbitten, in Sweden, has now issued its report, which states that more favourable conditions of production exist for coke pig-iron than for charcoal pig-iron. The cost of a standard blast furnace would be 7,900,000 crs. and that for an electric furnace at least 4,700,000 crs. The committee recommends that the plant be located at Lulea, while the annual capacity of the plant would be between 20,000 and 45,000 tons, according as coke and charcoal is employed for reduction purposes. The cost of production of coke pig-iron would be lower than that of charcoal iron, and would be roughly equal to that of imported coke pig-iron.

Carron Company

The Carron Company of Falkirk has published a well-illustrated and interesting booklet surveying the foundation (in 1759) and growth of the company and its position and achievements at the present day, on the occasion of the Empire Exhibition, Glasgow. The first cast of iron was made by the company in 1760, since when Carron have produced all classes of products from guns for Nelson and Wellington, through cylinders for James Watt's first steam engine, engines for the first steamship made in the United Kingdom, jewel dog grates and other architectural features of the Adams period, to the products of the modern large cooking apparatus, electric cooking and heating appliances, and structural departments. The booklet covers this period of development in an interesting manner and also describes in detail the scope of the present activities of the company.

Personal

MR. J. W. COX, formerly assistant manager of the furnace department of the Wellman Smith Owen Engineering Corporation, Limited, has joined the engineering staff of the Salem Engineering Company (England), as sales manager.

MR. JOSEPH WARD, J.P., chairman of Thos. W. Ward, Limited, has presented a portrait of Mr. George Wood, assistant managing director of the company, to be hung in the board room at Albion Works, Sheffield. Mr. Wood, who is principally interested in the scrap and shipbreaking activities of the business, joined the company in 1897, and was appointed a local director in 1919, a director in 1923, and assistant managing director in 1928. He is on the board of Marshall, Sons & Company (Successors), Limited, Gainsborough; Midland Iron Company, Limited, Rotherham; and Lowmoor Best Yorkshire Iron, Limited, Bradford, and is also chairman of the Committee of the Agency Firms in connection with the scrap iron and steel control scheme of the British Iron, Steel and Metals Association. He was President of the Yorkshire Scrap Iron, Steel and Metals Association from 1921 to 1923, and is a representative of the National Federation of Scrap Iron and Steel Merchants on the General Waste Materials Reclamation Trade Board.

Will

LAWRENCE, JOHN POST, managing director of Lloyds & Company (Letchworth), Limited, agricultural engineers, and of Lloyds & Company (South Africa), Limited	£75,556

Sir John Cass Technical Institute

The new session of the Sir John Cass Technical Institute, Jewry Street, Aldgate, London, E.C.3, which extends over about 36 weeks, will begin on Monday, September 26. Students will be enrolled on and after September 21. The Institute provides evening instruction in metallurgy and foundry practice, physics, chemistry, fuel technology, chemical engineering, assaying, and numerous other subjects. The evening courses are in general held from 6 to 10 p.m., whilst day courses are also provided in metallurgy, physics, mathematics, chemistry, etc. Full facilities are provided in well-equipped laboratories for special investigations and research.

The instruction in experimental science also provides systematic courses for the examinations of the University of London. These courses are conducted by recognised teachers of the University, so that matriculated students attending them can be registered and examined as "internal" students of the University. The courses provided also meet the requirements of those preparing for the examinations of the Institution of Gas Engineers and the City and Guilds of London Institute. At the recent examinations of the University of London, 30 students graduated in science and in metallurgy, of which number six obtained a first-class Honours Degree.

The Principal and heads of departments will be pleased to advise intending students at the commencement of the session on the course they should undertake.

Contract Open

Hereford, September 9.—Spun-iron pipes and cast-iron specials for six months commencing October 1, for the Town Council. The City Surveyor, Town Hall, Hereford.

Obituary

AT THE MOMENT of going to press we learn with regret of the death of Mr. W. E. McCalla, the London representative of Blythe Colour Works, Limited, Cresswell, Stoke-on-Trent. His career will be outlined in our next issue.

Patent Specifications Accepted

The following list of Patent Specifications accepted has been taken from the "Official Journal (Patents)." Printed copies of the full Specifications are obtainable from the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each. The numbers given are those under which the Specifications will be printed and abridged, and all subsequent proceedings will be taken.

486,219. FIRTH, SIR W. J. Production of metal sheets coated with tin or other metal or alloy.

486,232. HOUGHTON & COMPANY, E. F. Case-hardening iron and steel and salt baths therefor.

486,263. MASCHINENFABRIK WEINGARTEN VORM. SCHATZ AKT.-GES., H. Bending sheets of metal.

486,292. GLYNN BROS., LIMITED, and VENNELL, R. H. Apparatus for marking tubes, rods, bars, or the like.

486,329. REKUPERATOR GES. Air-heaters for blast furnaces.

486,407. THORNTON, A. A. (Dortmund Hoerder Hutten-Verein Akt.-Ges.). Sheet pile structures.

486,408. OSTERLIND, C. R. Muffles, annealing boxes, and the like.

486,480. RHODES, C. J. Presses for punching and drawing articles from sheet metal.

486,490. KLOCKNER-WERKE AKT.-GES. Method for the manufacture of sintered dolomite.

486,559. AMERICAN MAGNESIUM METALS CORPORATION. Electrically-heated furnace.

486,608-9. WILLIAMS, W. P. (American Rolling Mill Company). Annealing covers.

486,654. HUTTENWERKE SIEGERLAND AKT.-GES. Device for housing and conveying piles for sheet billets, semi-finished rolled products, sheets or other material to be pickled, in and out of a pickling tank.

486,805. FURNACE HOLDINGS, LIMITED (Buffalo Electric Furnace Corporation). Control of electric arcs particularly in electric furnaces.

486,857. EVERY, C. E. (Ferchland, P.). Improving iron and steel and alloys thereof.

486,908. FONDERIES FRANCAISES D'ACIERS SPECIAUX INOXYDABLES. Manufacture of ferrous alloys.

487,002. HARBISON WALKER REFRACTORIES COMPANY. Casting of metallic ingots.

487,024. WILSON, P. H., and STANTON IRONWORKS COMPANY, LIMITED. Pipe joints.

487,054. EICKWARTH, E. Continuous furnaces for the annealing of metal plates.

487,086. TRIGGS, W. W. (American Rolling Mill Company). Annealing furnace and method of operating the same.

487,151. LANGENOHL, M. Manufacture of centrifugally-cast ferrous metal tubes.

487,254. CLEVELAND TWIST DRILL COMPANY. Ferrous alloys.

487,262. MANNESMANNROHREN-WERKE. Chrome steel.

487,385. ALLMANNA SVENSKA ELEKTRISKA AKTIEBOLAGET. Methods of heating working pieces by means of high-frequency furnaces.

Company Reports

Ransomes & Rapier, Limited.—Interim dividend of 2½ per cent., free of tax, on the ordinary shares.

W. Canning & Company, Limited.—Interim dividend of 5 per cent. in respect of the six months' trading to June 30.

Blakey's Boot Protectors, Limited.—Final dividend of 7½ per cent. on the ordinary shares, making 15 per cent. for the year ended June 30.

Moss Gear Company, Limited.—Dividend of 3 per cent. for the half-year ending August 31 on the cumulative preference shares, making 6 per cent. for the year.

Brightside Foundry & Engineering Company, Limited.—Profit for year to June 30, after depreciation, income tax and N.D.C., £90,850; brought in, £20,957; preference dividend, £2,500; dividend of 15 per cent., and a special bonus of 10 per cent., on the ordinary shares, £43,750; to staff pension fund, £1,000; to reserve, £39,881; carried forward, £24,676.

International Foundry Congress

By a slip of the pen in our editorial last week, we wrote that the delegates to the Polish Congress would visit Witkowitz, when we intended to say Kattowitz.

TOR ROCK SAND
for the
FOUNDRY

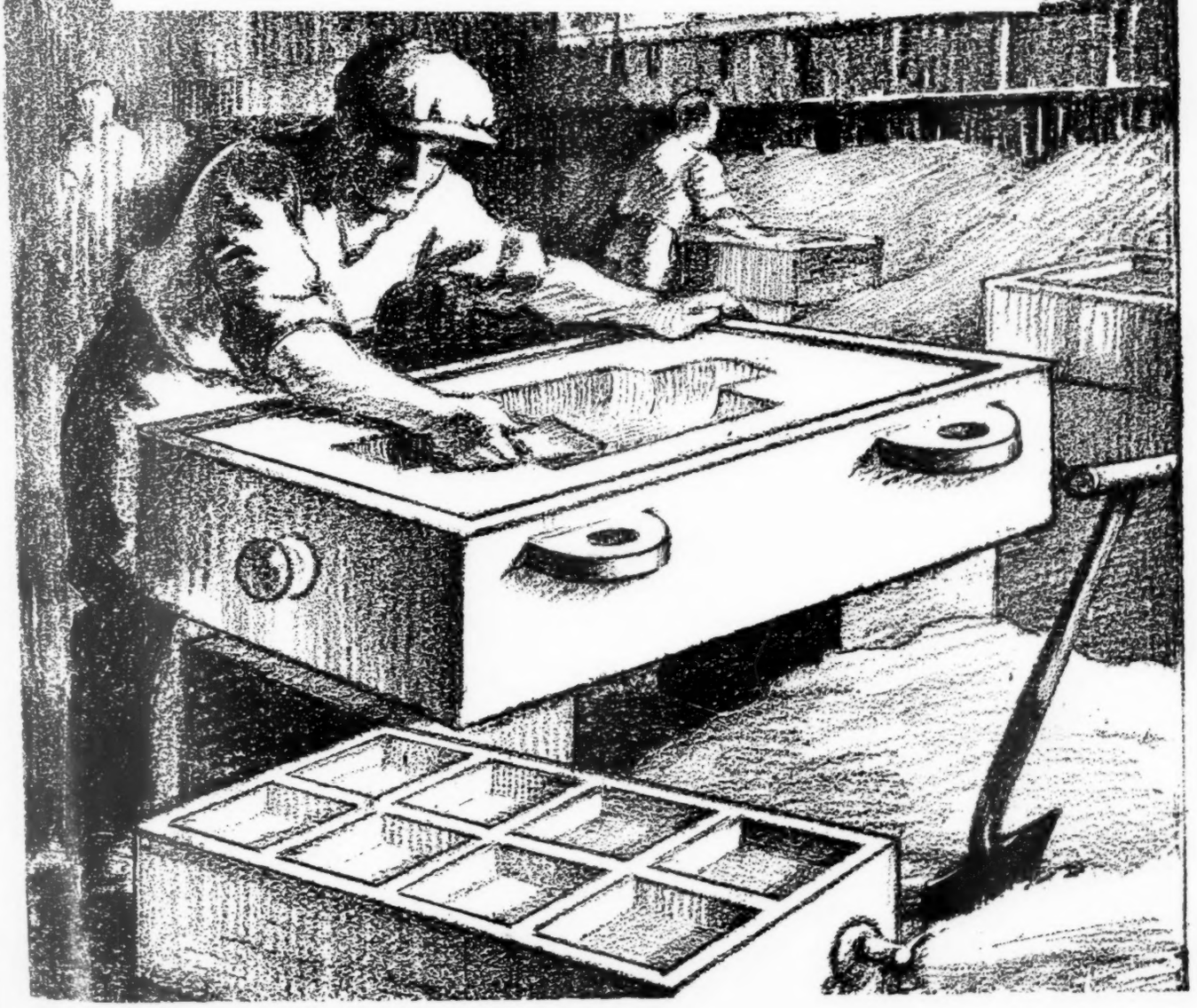
Higher casting temperatures in iron foundries—particularly in those where special alloys are melted—have resulted in a demand for a moulding sand to withstand severe conditions and produce sound castings of good finish. Tor Rock Sand has proved to be specially suitable for these requirements. It is coarse in grain and highly permeable and being somewhat irregularly graded, tends to give a strong and compact mould surface.

Please write for full particulars and sample:

GENERAL REFRACTORIES LIMITED
GENEFAX HOUSE, SHEFFIELD.

Telephone: 31113 (6 lines).

Telegrams: "Genefax, Sheffield."



Raw Material Markets

The iron, steel and metal markets show few signs yet of reviving activity. Holiday influences are gradually being shaken off, but consumers appear to be in no hurry to place fresh orders, and the volume of new business circulating is small. Contracts for heavy steel carry a rise and fall clause, but consumers of pig-iron and other ferrous materials will aim to have their stocks as low as possible on December 31, as they expect reductions in prices for next year's deliveries. Therefore, although stocks have been reduced, it is unlikely that much business other than in small lots to meet current requirements will be placed for a month or two yet, or until some indication of 1939 prices is forthcoming. A substantial revival of activity at the consuming end would, of course, alter the situation, but at the moment users' order-books are not such as to make them anxious buyers of iron and steel.

Pig-Iron

MIDDLESBROUGH.—Quiet trading conditions still prevail in the pig-iron trade on the North-East Coast. Many of the foundries are covered until the end of the year by running contracts, and those that are not show no disposition to commit themselves further except for parcels to cover current needs. Consumers are confident that prices will move in their favour at the end of the year, and this factor, apart from quiet trade at foundries and ironworks, tends to limit business severely. Local and Scottish users of Cleveland iron are buying very little, and there is no compensating outlet abroad. Production of ordinary Cleveland iron is suspended—has been, indeed, for some time—but makers have ample stocks to meet requirements, and it would need a considerable increase in demand to warrant a resumption of output. Fixed prices for delivery in the Middlesbrough or Falkirk areas are: No. 3 Cleveland G.M.B., 109s.; No. 1 foundry, 111s. 6d.; No. 4 foundry and No. 4 forge, 108s. per ton, less 5s. rebate.

Quiet trading conditions also rule in regard to East Coast hematite. A fair tonnage is being delivered under running contracts, but consumers are placing few fresh orders, and the iron already sold is not being taken out at the rate desired by makers. Fixed zone prices rule until the end of the year, and for mixed numbers are:—North-East Coast, 132s. 6d.; Sheffield, 138s.; Manchester, 140s. 6d.; Midlands, 143s. 6d., less 5s. rebate.

LANCASHIRE.—Stocks at foundries have been reduced, but deliveries from the furnaces show little expansion, and the volume of fresh business passing is small. Where orders are being placed, they are restricted to small tonnages to meet users' month-to-month needs. This policy is likely to continue until some announcement of prices for next year's delivery is forthcoming. Light-castings makers are reported to be slightly busier, but the movement has not gone very far. Heavy electrical engineers and machine-tool makers continue to take good tonnages, but textile machinery makers and the jobbing foundries are only quietly engaged. Staffordshire and Derbyshire brands of No. 3 foundry iron are quoted on the basis of 114s. for delivery in the Lancashire price zone, less a loyalty rebate of 5s., with Northamptonshire No. 3 at 112s. 6d., and Derbyshire forge iron at 111s. to 113s., according to the class of user. West Coast hematite is 141s., delivered, and East Coast 140s. 6d. Scottish No. 3 foundry iron is quiet at around 137s. 6d., delivered equal to Manchester.

MIDLANDS. — The ordinary high-phosphoric grades of pig-iron used in this area go mostly to the light-castings establishments, and the demand cannot improve while these consumers are poorly engaged. The demand for light castings for the building trade has not improved, and so far as this important consuming industry is concerned, any expansion of demand seems unlikely now, in view of the fact that builders have the autumn and winter months before them. There is less iron in stock at the foundries, but little fresh buying is being done. More interest is being displayed in low-phosphoric grades of pig-iron, the heavy engineering trades, who are the chief consumers, being busy. There is some improvement in the call for deliveries of hematite against contracts, but the iron is not being taken out at the rate the furnaces would like, and very little fresh business is being placed.

SCOTLAND.—The light-castings trade is working short time, and stocks are being reduced very slowly. Consequently, new business in Cleveland brands is scarce. Prices are fixed until the end of the year at 109s., f.o.t. Falkirk, and 112s., f.o.t. Glasgow, for No. 3 Cleveland. Demand for Scottish iron also shows no improvement. The number of furnaces in operation has been reduced to nine, and their output is more than sufficient for current requirements. Quotations for Scottish iron are 120s. 6d. for No. 1 and 118s. for No. 3, f.o.t. furnaces. Steelmakers are slow in taking delivery of the iron they have contracted for, there being a large tonnage of basic, particularly, in store at steelworks' yards. Quotations for steel-making iron are unchanged at 133s. for hematite mixed numbers, 107s. 6d. for Scottish basic, and 100s. for English and Indian basic, all less 5s. rebate, delivered.

Coke

The foundry coke market follows the pig-iron position, and at the moment slack conditions rule. In view of the fact that the makers have surmounted the summer months without being compelled to make further reductions, it is not thought that lower prices will operate before the end of the current year. For delivery to Birmingham and Black Country stations, best Durham coke is quoted at 30s. 6d., with Welsh coke at from the same figure up to 62s. 6d. per ton.

Steel

Inquiry is expanding in the steel markets as the holiday season draws to a close, but the amount of actual business transacted remains disappointing, and the works in all sections of the industry have materially reduced the reserve of orders upon their books. The situation in the semi-finished steel department has improved somewhat with the liquidation of a good proportion of the heavy stocks which weighed upon the market, and there has been an expansion in the demand for British material. At the present rate of consumption, however, it will be late in the year before the accumulations in the hands of users are absorbed. The demand in the finished steel market is irregular, but apparently the decline in the volume of business has been checked, and hopes are entertained of a revival in the early autumn. The heavy steel works have still large tonnages to deliver against contracts; but fresh orders are badly needed. In the lighter branches of the industry business has improved, but plants are operating at below capacity. The demand on export account has been on a restricted scale.

Scrap

The iron and steel scrap market is still very quiet. Prices of steelworks' scrap are due for revision at the end of September, and a meeting between the merchants and the steelworks is to take place during the next few days to discuss questions of prices and conditions over the remainder of the year. Merchants find their yards over-stocked at the moment, and they will seek an alleviation of the position. What will be done with regard to prices remains to be seen, but it hardly seems possible that a reduction would improve trade, and it is probable that prices will be left unchanged for the time being, at least till the end of the year.

Metals

Copper.—The tense situation in Europe during the past week, arising out of the Czech problem, has affected the copper market, which has lost some ground. The standard market was subjected to some heavy liquidation, and the underlying strength of the metal is apparent in the comparatively limited fall in prices. An improvement in international conditions should be quickly reflected in the copper market.

Metal Exchange quotations were as follow:—

Cash.—Thursday, £40 12s. 6d. to £40 15s.; Friday, £40 16s. 3d to £40 17s. 6d.; Monday, £40 to £40 1s. 3d.; Tuesday, £40 1s. 3d. to £40 3s. 9d.; Wednesday, £40 6s. 3d. to £40 7s. 6d.

Three Months.—Thursday, £40 17s. 6d. to £41; Friday, £41 1s. 3d. to £41 2s. 6d.; Monday, £40 5s. to £40 6s. 3d.; Tuesday, £40 7s. 6d. to £40 8s. 9d.; Wednesday, £40 10s. to £40 11s. 3d.

Tin.—Prices on the standard tin market have fluctuated within narrow limits. There has been no strong factor to influence the market and quiet conditions have ruled. It cannot be said that consumption shows much expansion either here or in the United States, though the Welsh tinplate industry is certainly slightly busier. Statistics published in the August bulletin of the International Tin Research and Development Council, show that 82,600 tons of tin were produced in the first half of the current year, against 94,600 tons in the first half of last year. World apparent consumption of tin in the first half of the year, at 80,900 tons, was about 17½ per cent. below the figure for the first half of 1937.

Official quotations were as follow:—

Cash.—Thursday, £193 5s. to £193 10s.; Friday, £193 to £193 10s.; Monday, £190 10s. to £190 15s.; Tuesday, £192 to £192 5s.; Wednesday, £192 15s. to £193.

Three Months.—Thursday, £194 5s. to £194 10s.; Friday, £194 to £194 5s.; Monday, £191 10s. to £191 15s.; Tuesday, £193 to £193 5s.; Wednesday, £193 15s. to £194.

Spelter.—This market remains quiet. Discussing the prospects of the metal, Rudolf Wolff & Company state: "Outside interests still continue apathetic towards this metal, and judged on its own merits there does not seem very much prospect of a material advance. At the same time, if the production of lead is restricted, this will have a direct bearing on spelter, as this metal is mainly produced as a mining by-product of lead, and any ease-up in the mining of lead ore would lessen the output of zinc ore also."

Daily market prices:—

Ordinary.—Thursday, £13 3s. 9d.; Friday, £13 2s. 6d.; Monday, £13 2s. 6d.; Tuesday, £13 2s. 6d.; Wednesday, £13 8s. 9d.

Lead.—This metal has been quiet and, on the whole, easier. Speculation continues as to the possibility of bringing into force a scheme of output control and as to the effect of such action on supplies. Trade demand in this country is quiet.

Day-to-day quotations:—

Soft Foreign (Prompt).—Thursday, £14 11s. 3d.; Friday, £14 11s. 3d.; Monday, £14 6s. 3d.; Tuesday, £14 2s. 6d.; Wednesday, £14 5s.

Scrap.—Dull conditions continue to rule in the market for non-ferrous scrap. Supplies are plentiful. There is little change in prices.

Approximate selling prices for old metal:—New aluminium cuttings, £67; rolled, £52; cast, £28; foil, £88 to £90. Copper, £36 to £40; braziery, £32. Brass (clean), £21 to £24. Zinc, £8 10s. Lead, £13. Gunmetal, £38.

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